NINA Report 505

“Pre- and post-construction studies of conflicts between birds and wind turbines in coastal Norway” (Bird-Wind)

Progress Report 2009

Kjetil Bevanger, Finn Berntsen, Stig Clausen, Espen Lie Dahl, Øystein Flagstad, Arne Follestad, Duncan Halley, Frank Hanssen, Pernille Lund Hoel, Lars Johnsen, Pål Kvaløy, Roel May, Torgeir Nygård, Hans Christian Pedersen, Ole Reitan, Yngve Steinheim, Roald Vang

CEDREN Centre for Environmental Design of Renewable Energy

Forskningsrådet Statkraft Norges vassdrags- og energidirektorat NVE EBL Energibedriftenes landsforening

NINA Norwegian Institute for Nature Research

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COVER PICTURE
Statkraft Headqaurter within the Smøla wind-power plant area with the project research facilities in front (white barracks).
Photo: Kjetil Bevanger

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Abstract

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From 2007 inclusive, NINA has received economic support for research on wind power and birds from the Norwegian Research Council (NFR) through the RENERGI-programme. The project is named *Pre- and post-construction studies of conflicts between birds and wind turbines in coastal Norway* (BirdWind). BirdWind is approaching its finalisation; with 2010 as the last ordinary year where data-collecting activities takes place. In 2009 the project was significantly strengthened through a new PhD-position funded by Statkraft and NINA. The position is held for four years, and the overall aim of the work conducted by the PhD-student is to model the future white-tailed eagle (WTE) population development based on reproduction and mortality data. Weekly searches with dogs for birds killed within the wind-power plant have been carried out throughout the year; in general searches are conducted every 7 days (plus or minus one day). 25 ‘primary turbines’ are selected and searched together with one of two dogs. A full search of all turbines is performed at larger intervals. In 2009 (up to December 1) 31 specimens of at least 8 species have been recorded. The most frequent victims are willow ptarmigan and WTE with 10 and 7 carcasses, respectively. Of waders 3 common snipes have been recorded. Five carcasses were recorded of hooded crow, and single carcasses of parrot crossbill, northern wheatear, teal and mallard. Some records from earlier years have been revised as collision victims or not. Also in 2009 censuses for willow ptarmigan have been carried out in spring and autumn on Smøla and Hitra. The preliminary results do not indicate any obvious differences between the two areas, but autumn density in the wind-power plant area seems to be more stable compared to the control area. Interestingly the higher density within the wind-power plant area in autumn is evened out in spring each year, so also in spring 2009. To obtain data on habitat selection, movements, collision risks, survival of eggs, chicks and adults and general population dynamic parameters, willow ptarmigan specimen have been radio-tagged in 2008-2009. The activities regarding breeding waders and small birds (mainly passerines) have this year focused on the EIA-activities on Hitra in connection to the planned extension of the existing power plant on Hitra I; the Hitra II Wind-Power Plant. Since 2003, 50 nestlings of white-tailed eagle have been equipped with satellite transmitters. In 2009, eight WTE nestlings were tagged, six with solar-powered and two with battery-powered transmitters. One was tagged within the wind-power plant, the others in close vicinity of it. The solar-powered transmitters used in 2009 were programmed to give one position per hour during summer in order to have finer resolution of movements for risk-modelling purposes. During winter less frequent downloading is scheduled, due to low light and poor battery-charging. One of the tagged nestlings was found killed by a turbine October 7. We have continued to collect feathers from active nests and chicks also in 2009, as well as from eagles killed in collisions with wind turbines. DNA-analyses from bones of six eagles killed by electrocution on power-line pylons on Smøla will also be included. For increased efficiency in the laboratory, and to streamline the production of DNA-data, the use of an extraction robot has been implemented. All WTE nest sites on Smøla were surveyed during the summer. Territorial activity, identified by either moulted adult feathers, chicks in the nest or fresh nest material, was confirmed in 61 different territories on the main island and in the surrounding archipelago. In these territories 27 chicks from 21 different clutches were recorded. This is the second highest number of chicks recorded ever on Smøla, giving a reproductive output of 0.44 chicks/confirmed occupied territory. In order to investigate behavioural differences for the WTE related to the distance from the turbines, data on flight activity (moving flight, social behaviour and soaring) and flight height (below, in and above the rotor zone) were collected at 12 vantage points, 6 from inside the wind-power plant area and 6 from control areas close to the power-plant area. The results indicate that the WTE on Smøla does not have any behavioural responses to the wind-power plant constructions. It may, however, contribute to explain why the WTE is vulnerable to collisions with the turbines and the number of killed individuals re-

corded within the power-plant area. The results may also contribute to explain the high percentage of adults found killed in the wind-power plant area. The WTE has a peak activity early in the breeding period, which can be fatal to both adult individuals, and thus also to the nestlings. In 2009, all 30 dead WTEs recorded in connection to the wind-power plants on Smøla and Hitra have been examined. The eagle carcasses varied considerably with respect to what a post-mortem examination could reveal, and the condition of most carcasses did not allow for a thorough classic autopsy. All eagles were x-rayed and their damages were described. Three willow ptarmigan and one merlin recorded on Smøla were also autopsied. The precise findings and assessment will be presented later. Seven camera systems were developed and deployed during spring 2008, and have been collecting data throughout the year. For the time being several terabytes is waiting to be analysed. The reason for this is that the system has a malfunction, being triggered by other movements than those of birds. How to proceed with the data analyses will be discussed on a meeting with Statkraft in January 2010. The main focus regarding the avian radar has been the development of GIS-tools to learn more about the radar range and scanning accuracy, development of database routines to optimize radar data (including false alarms filtering and categorization of bird tracks using data-mining techniques). Experimental tests of the radar performance with respect to accuracy in detecting and following birds was done using model aircrafts and ground-truthing (identify bird species spotted by the radar by field observations). Methodological challenges of the radar system are to which extent the tracking-algorithm is able to record bird flights, the verification of recorded radar tracks to species and the characterisation of species-specific track-characteristics to enable extrapolation to the entire database. We have developed a web application, “WebTracks”, which allows radar tracks to be visualized together with ground-truthed data. This gives an instant view of where the radar might have low visibility. It also visualizes where the radar looses track of the object, and splits tracks into multiple segments, where they should have been contiguous. By selecting and displaying ground-truthed data, or model-aircraft tracks, together with tracks from the radar database in the same time interval, an instantaneous overview of the radar-tracking capabilities can be obtained. It is possible to overlay both topographical maps, and clutter maps in the map window of the application. Together with colour coding of the objects height, the clutter map indicates where the object should be visible for the radar. Based on laser elevation data from the laser scanning of Smøla in 2008 a high resolution terrain model was established in March 2009. The LIDAR data was delivered in LAS-format. The LIDAR DEM-model is an important input in the modelling of theoretical land-clutter areas and areas with wind-turbine interference. These clutter and interference areas reduce the radar detection performance and have to be flagged as clutter in the database. The land-surface clutter model is nearly completed, but has to be further improved and tested before it is applied into the database as a mask to flag clutter pixels. This is an important step in order to be able to interpret the database.

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Sammendrag

Bevanger, K., Berntsen, F., Clausen, S., Dahl, E.L., Flagstad, Ø. Follestad, A., Halley, D., Hanssen, F., Hoel, P.L., Johnsen, L., Kvaløy, P., May, R., Nygård, T., Pedersen, H.C., Reitan, O., Steinheim, Y. & Vang, R. 2009. "Pre- and post-construction studies of conflicts between birds and wind turbines in coastal Norway" (BirdWind). Progress Report 2009. – NINA Rapport 505. 70 s.

Fra og med 2007 har NINA mottatt økonomisk støtte til forskning på effekter av vindkraftproduksjon på fugl fra Norges Forskningsråd gjennom RENERGI-Programmet. Prosjektet heter *Pre- and post-construction studies of conflicts between birds and wind turbines in coastal Norway* (BirdWind). BirdWind går nå inn i sin sluttfase, med 2010 som det siste ordinære år med datainnsamling. Prosjektet ble betydelig styrket i 2009 ved at det ble ansatt en PhD-student som særlig skal fokusere på den fremtidige bestandsutviklingen hos havørn, basert på reproduksjons- og dødelighetsdata. Arbeidet vil gå over fire år og stillingen er finansiert av Statkraft og NINA. Ukentlige søk etter døde fugler innen området til vindkraftverket har pågått hele året, og generelt har det vært gjort søk med 7 dagers intervall (pluss/minus én dag) i tilknytning til 25 utvalgte "primærturbiner". Søkene har vært utført sammen med hund. Søk ved alle møller har vært gjort med lengre mellomrom. De vanligste artene som er funnet er lirype og havørn, med henholdsvis 10 og 7 individer (frem til 1. desember). Det er også funnet 3 enkeltbekkasiner, samt 5 kråker, og ett individ av henholdsvis furukorsnebb, steinskvett, krikkand og stokkand. Noen funn fra tidligere år er reklassifisert i forhold til dødsårsak. Vår- og høsttaksering av lirype er foretatt som tidligere både på Smøla og Hitra. Foreløpige resultater indikerer ikke spesiell forskjell mellom de to områdene, men høstbestanden i området til vindkraftverket på Smøla synes å være mer stabil sammenlignet med kontrollområdet. Interessant nok synes den tilsynelatende høyere bestandstettheten innen området til vindkraftverket om høsten å jevne seg ut om våren; så også i 2009. For å samle data på habitatseleksjon, bevegelser, kollisjonsrisiko, eggpredasjon, unge- og voksenoverlevelse, samt generelle parametre i forhold til populasjonsdynamikk, har ryper blitt radioinstrumentert både i 2008 og 2009, et arbeid som fremdeles pågår. Aktivitet i tilknytning til vadere og mindre fugler har i inneværende år vært lagt til Hitra i tilknytning til konsekvensutredningsarbeidet i forbindelse med planene om en utvidelse av vindkraftverket der (Hitra II). Siden 2003 har 50 reirunger av havørn blitt utstyrt med satellittsender med GPS funksjon. I 2009 ble 8 havørnunger radioinstrumentert, 6 med solcelledrevne sendere, og 2 med batteridrevne. Én ble merket innenfor området til vindkraftverket, de andre i tilgrensende områder. De solcelledrevne senderne brukt i 2009 er programmert til å gi én posisjon hver time om sommeren for å gi et mer detaljert bilde av bevegelsesmønsteret; data som skal brukes til risikomodellering. Om vinteren sendes langt færre posisjonsdata pga. lite lys og dårlig batteri-lading. En av årets satellittmerkede unger ble funnet turbindrept 7. oktober 2009. Fjærinnsamling har pågått som tidligere både fra aktive reir og reirunger, så vel som fra ørner drept i tilknytning til vindturbinene. DNA-analyser fra bein av 6 ørner drept i elektrokusjonsulykker (strømslag) på Smøla er også inkludert i materialet. For å øke laboratorieeffektiviteten og for å strømlinjeforme produksjonen av DNA-data, er en ekstraksjonsrobot tatt i bruk. Alle havørnreir på Smøla ble kontrollert også i sommer. Territorieaktivitet, identifisert enten ved mytefjær, reirunger eller friskt reirmateriale, ble konstatert for 61 territorier på hovedøya og tilgrensende småøyer. Til sammen ble det fra disse territoriene registrert 27 reirunger fra 21 forskjellige territorier. Dette er det nest høyeste antall reirunger som noen gang er registrert på Smøla, og gir en reproduksjonsrate på 0,44 reirunger/okkupert territorium. For å undersøke mulige atferdsforskjeller hos havørn i forhold til avstand fra vindturbinene, er det samlet data på flygeaktivitet (forflytting, sosial atferd og sveving) og flygehøyde (under, i og over rotornivå) fra 12 utkikkspunkter; 6 inne i området til vindkraftverket og 6 fra kontrollområder utenfor. Resultatene indikerer at havørner på Smøla ikke responderer atferdsmessig på vindturbinene. Dette kan bidra til å forklare hvorfor havørn er utsatt for å kollidere med vindturbiner og antall drepte ørner funnet i tilknytning til vindkraftverket på Smøla. Det kan også bidra til å forklare den forholdsvis høye andel voksenfugler som er funnet drept da havørn har en aktivitetstopp i begynnelsen av hekkeperioden, noe som kan være fatalt både for voksne og reirunger. I 2009 er alle 30 døde havørner funnet i tilknytning til vindkraftverkene på Smøla og Hitra underkastet veterinærmedisinsk obduk-

sjon, inklusive røntgenfotografering. De døde fuglene har variert betydelig i forhold til i hvilken utstrekning det har vært mulig å gjennomføre en post-mortem undersøkelse, og tilstanden til de fleste har ikke tillatt en grundig, klassisk obduksjon. Tre liryper og en dvergfalk er også blitt undersøkt. Detaljerte resultater vil bli publisert senere. De 7 kameraene som ble montert i tilknytning til turbin 43 våren 2008 har samlet data gjennom hele året. Per dags dato er det lagret flere terrabyte som avventer analyse. Årsaken til dette er en svakhet i systemet som gjør at kameraene utløses av andre årsaker enn fugl i bevegelse. Hvordan videre databearbeiding skal skje vil bli avgjort på et møte med Statkraft i januar 2010. Hovedfokus for arbeidet med fugleradaren har vært utviklingen av GIS-verktøy for å lære mer om radarens rekkevidde og registreringsfølsomhet, utvikling av databaserutiner for å optimalisere radardataene (inklusive filtrering av falske signaler og kategorisering av fugle-spor (”tracks”) v.hj.a. datautvinningsteknikker (”datamining”). Det er også gjort eksperimentelle tester av radarens ytelse i forhold til hvor nøyaktig den er når det gjelder å oppdage og følge fugler. Til dette er det benyttet modellfly og bakkeverifisering (dvs. visuell identifisering av fugler som radaren registrerer). Metodiske utfordringer angående radarsystemet ligger i forhold til i hvilken grad sporings-algoritmen klarer å registrere fugler i flukt, verifisering av registrerte radarspor vis a vis arter, og karakterisering av artsspesifikke sporkarakteristika som kan ekstrapoleres til hele databasen. Vi har utviklet er web-applikasjon (”WebTracks”) som muliggjør visualisering av radarspor sammen med bakkeverifiseringsdata. Dette gir et øyeblikksbilde av hvor radaren har lav dekningsgrad. Det visualiserer også hvor radaren mister sporet av et objekt og splitter sporene i flere segmenter hvor de skulle vært sammenhengende. Ved å selektere og vise bakkeverifiserte data, eller sporene fra modellflyet, sammen med sporene fra radardatabasen fra samme tidsintervall, er det mulig å få et øyeblikksbilde av radarens sporingsevne. Det er mulig å legge på både topografiske kart og kart over falske signaler (”clutter map”) i applikasjonens kartvindu. Sammen med fargekoding av objektets høyde indikerer kartet med falske alarmer hvor objektet skulle vært synlig for radaren. Gjennom laserregistrerte høydedata, dvs. data basert på laser-scanning av Smøla i 2008, fikk vi laget en høyoppløselig terrengmodell i mars 2009. LIDAR-dataene (LIDAR=Light Detection And Ranging; dvs. en optisk fjernmålingsteknikk som måler egenskaper ved spredt lys for å finne avstand til, eller annen informasjon, knyttet til et fjerntliggende objekt) ble levert i LAS-format (dvs. et filformat som muliggjør utveksling av 3-dimensionale punktdata). LIDAR-høydemodellen er et viktig bidrag i arbeidet med å modellere de teoretiske bakke-clutterområdene og områder med forstyrrelse/interferens fra vindturbinene. Områdene med falske signaler og interferens reduserer radarens oppdagelsesevne og må merkes som falske signaler i databasen. Modellen for bakke-clutter er snart ferdig, men må raffineres og testes før den benyttes i databsen som filter for falske pixler. Dette er et viktig steg fremover i forhold til å gjøre oss i stand til å tolke/bearbeide dataene i databasen.

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Contents

Foreword

From 2007 inclusive, NINA has received economic support for research on wind power and birds from the Norwegian Research Council (NFR) through the RENERGI-programme. The project is named *Pre- and post-construction studies of conflicts between birds and wind turbines in coastal Norway* (BirdWind). It is a capacity building project with user participation (KMB). The project has a comprehensive and challenging goal framework, economically as scientifically, and can only be carried out through a close cooperation with the central energy and environmental management together with the wind-power plant owners. In addition to the Norwegian Water Resources and Energy Directorate (NVE), the Norwegian Electricity Industry Association (EBL), and Statkraft at the outset committed themselves to contribute an annual economic support to the project (at least 20% of the total costs). Additionally Statkraft guaranteed a considerable economic support for, among other things, the purchase of a bird radar system which became operative in March 2008. In the course of 2007-2009, the environmental management authorities (The Ministry of Environment and The Directorate for Nature Management) and NVE have contributed economically both to existing and new research modules under the project umbrella. In spring 2008 NINA was invited by NFR to apply for extra funding for the project and received in September an extra grant of NOK 1.5 mill. for "*Data flow and storing, visualisation and modelling*". In spring 2009 the project was integrated in CEDREN – i.e. the *Centre for environmental design of renewable energy*. CEDREN is one of 8 centres for Environment-friendly Energy Research (CEER) in Norway. The establishment of the CEER scheme is a direct response to the broad-based agreement on Norway's climate policy in the Norwegian Parliament (Stortinget), reached early in 2008, and the adoption of the national R&D strategy *Energi21.* Norway has decided to earmark at least NOK 100 million per year to the CEER initiative. For the Norwegian research institutions the application process started in May 2008 and a final decision on the winners was taken by the Research Council Executive Board on 28 January 2009, and the official announcement was made by the Minister of Oil and Energy February 4 2009. CEDREN is a consortium with SINTEF, NTNU and NINA as key institutions. SINTEF is responsible for co-ordinating the CEDREN activities and the basic funding comes from NFR, together with users like Statkraft, EBL, NVE etc. Thus the basic activities within CEDREN are based on the ongoing activities in BirdWind and 6 other KMB projects. The overall objective of CEDREN is to *develop and disseminate effective design solutions for renewable energy production that take adequate account of environmental and societal issues, both locally and globally*.

Trondheim, 1 December 2009

Kjetil Bevanger
Project leader

1 Introduction

Since 1999 NINA has conducted research and EIA activities related to wind-power development projects and birds (with special focus on white-tailed eagles). The basic funding has come from NVE and Statkraft, but also from EBL, DN/MD, Norsk Hydro, RSPB and AMEC (Follestad et al. 2007, Bevanger et al. 2008a, b).

In December 2006 NINA received funding from NFR to the project application *"Pre- and post-construction studies of conflicts between birds and wind turbines in coastal Norway"* (BirdWind) (within the RENERGI Programme). The project activities up to December 2008 are reported by Bevanger et al. (2008b), and this report summarises the 2009-activities. Although the project is scheduled for the period 2007-2010, some of the activities will continue beyond 2010. A meeting with Statkraft in January 2010 will decide on whether or not the activities will continue within a new framework, with particular focus on mitigating measures. NFR has also approved an application from NINA to prolong the project period by one year; i.e. up to December 31 2011. Thus the final reporting will take place in 2011.

1.1 PhD position

The project is significantly strengthened through a new PhD-position funded by Statkraft and NINA. The position is held for four years by Espen Lie Dahl (Photo 1), and the overall aim in his work is to model the future white-tailed eagle (WTE) population development based on reproduction and mortality data. An important question to answer is the local, regional or national population implication of an additional mortality factor like the one imposed by the Smøla Wind-Power Plant.

Photo 1. *Espen Lie Dahl is the new PhD student on the BirdWind Project. Here with a lobster soon ready to be eaten by the attendees of the voluntary fieldwork regarding searches for electrocuted birds on Smøla in November.* Photo: Kjetil Bevanger.

1.2 Information and dissemination

BirdWind is a project addressing issues with a significant level of public interest – and conflict - in Norway. Thus the information strategy is based on a dialogue with the energy industry, management authorities as well as information to the public - locally, regionally and nationally. The Annual Progress Report of course is an important part of this. The media, i.e. newspapers, magazines radio and television are focusing the project several times during a year (cf. Chapter 3). On request the team members also meet school classes, student groups, politicians etc. giving lectures on the project and ecological effects of wind power in general during site visits and on other occasions (Photo 2).

Photo 2. *Roel May elaborating on the bird radar to employees at the University of Science and Technology (NTNU) visiting the power-plant area in early spring.* Photo: Kjetil Bevanger.

1.3 Research facilities

The efforts to establish research facilities within the power-plant area designed for the project was finalized in May; including barracks with 6 bed rooms, kitchen, lounge and meeting room; a significant investment which have strengthened the project by e.g. removing the need for external accommodation (Photo 3).

Photo 3. *In early May 2009 the accommodation facilities made available by Statkraft for the project team was ready. For sure it makes life easier during the fieldwork periods!* Photo: Kjetil Bevanger.

1.4 The Annual Meeting

The two day Annual Meeting was also in 2009 organised on Smøla. The following persons participated: **NINA** – *The Norwegiuan Institute for Nature Research*: Kjetil Bevanger, Stig Clausen, Espen Lie Dahl, Arne Follestad, Jan Ove Gjershaug, Duncan Halley, Frank Hanssen, Pernille Lund Hoel, Roel May, Hans Christian Pedersen, Ole Reitan, Oddmund Rønning. **SINTEF -** *The Foundation for Scientific and Industrial Research at the Norwegian Institute of Technology*: Lars Johnsen, Yngve Steinheim. **The University of Uppsala**: Olle Håstad, Diana Rubene. **RSPB** – *The Royal Society for the Protection of Bird*s, *UK*: Rowena Langston. **Statkraft**: Bjørn Iuell, Tormod Schei, Arild Soleim. **EBL** - *The Norwegian Electricity Industry Association*. **NERI** – *The National Environmental Research Institute*, *Denmark*: Mark Desholm. **NVE** - *T*he *Norwegian Water Resources and Energy Directorate*: Nils Henrik Johnson, Lars Håkon Bjugan. **DN** – *The Directorate for Nature Management*: Jo Anders Auran, Snorre Stener.

Photo 4. *Bjørn Iuell, Tormod Schei and Rowena Langston studying the latest news (on wind power?) in the local press at the Annual Meeting on Smøla in 2009.* Photo: Kjetil Bevanger.

Photo 6. *Project-team members Ole Reitan, Jan Ove Gjershaug and Arne Follestad taking a break from the Annual Meeting enjoying the atmosphere of a late winter snow-fall on Smøla*. Photo: Kjetil Bevanger.

1.5 Additional funding

NFR invited some of the ongoing projects within the RENERGI Programme to apply for extra funding in spring 2008, and in October 2008 NINA received a message from NFR that “part D” of the application for additional funding was approved with NOK 1.5 mill. Part D focused “Data flow and storing, visualisation and modelling”. The application describes the work in Part D in this way:

“To automate on-demand processing of raw radar data, we will implement program logic in the data server to fetch the correct files from the storage library, process these with a set of parameters, and then assure that these processed data are stored in a database separated from the original processed data. It will also be necessary to “tag” these data with the processing metadata for later comparison and documentation. For realisation of the visualisation and modelling tasks all relevant geographical data from Norge Digitalt will have to be organised into File Based Geodatabases using ArcGIS ArcCatalog and ModelBuilder.

Detected bird flight behaviour served from the technical infrastructure will be visualised in a terrain model using ArcGIS with 3D Analyst, ArcGlobe and Tracking Analyst. Flythroughs from these applications will be made accessible in a web-interface, as predefined video-formats or as KML-format for Animation in Google Earth. The correlation studies between detected bird flight behaviour and corresponding parameters will be modelled in ArcGIS using raster format (GRID), raster calculation and statistical methodology. The causality maps will be produced thematically, made accessible in a web-interface and be downloadable as predefined video-formats, geographical formats (GRID, IMG, KML, Shape, SOSI) and WEB- services (Web Map Services, and Web Feature Services).

Finding the best prediction model for identification of potential conflict areas between birdlife and wind-energy production demands a thoroughly literature survey. A main challenge will be to find a model that handles dynamic data (such as bird activity, climate and wind conditions) in an appropriate way. When we finally have selected a model we will have to define criteria and critical threshold values to be applied in the model. All the modelling activities will be done using ArcGIS with Modelbuilder 3D Analyst, ArcGlobe and Spatial Analyst. Finally the results of the prediction modelling will be visualized in a 3D terrain model using ArcGIS with 3D Analyst and ArcGlobe. The result of the visualisation will be made accessible in a web-interface, as predefined video-formats, geographical formats (GRID, IMG, KML, Shape, SOSI) and WEB-services (Web Map Services, and Web Feature Services).”

This additional funding has made it possible to take this part of the project a significant step forward, and will improve the final output of several subprojects.

1.6 Meeting with the Bern Convention secretariat

In 2002 Norway was reported to the Bern Convention by BirdLife International on behalf of the Norwegian Ornithological Association (NOF). The Bern Convention, to which Norway is a signatory, was set up to protect Europe’s wild plants, animals and their habitats. Representatives from the convention secretariat came on a “On the spot Appraisal” on June 15-17 and met with representatives from all involved parties from the environmental and energy authorities, Statkraft and NOF. The main objective for the secretariat was to investigate the claim that Norway did not consider the environmental factors to a satisfactory degree when issuing the licence for the construction of the Smøla Wind-Power Plant. Three representatives from NINA/BirdWind were invited to present the project for the attendees, including the contributions made by NINA regarding the EIA-process initiated in 1999 (Photo 7 and 8).

Photo 7. *Statkraft representatives attending the meeting with members from the Bern Convention Secretariat on Smøla June 16*. *From the left: Bjørn Iuell, Tormod Schei and Arild Soleim.* Photo: Kjetil Bevanger.

The Terms of Reference given to the expert (Eckhart Kuijken) by the Bern Convention Secretariat (Kuijken 2009) was to

- *Examine the two wind farm complexes in the Archipelago of Smøla, Norway, in an area of importance for the nesting of White-tailed Eagles and other species*
- *Assess the detrimental impacts on the fauna and flora species and their natural habitats, including the potential cumulative effect of the proliferation of wind farms within the Norwegian range of the White-tailed Eagle*
- *Assess the existing mortality surveys and the ongoing research project conducted by the Norwegian Institute for Nature Research (NINA) addressing the following long-term effects of the windmills on the White-tailed eagle: reduced breeding population; increased adult mortality; reduced breeding success; and increased juvenile mortality*
- *Discuss with all relevant authorities as well as representatives of associations and NGOs*
- *Make appropriate recommendations to the government*
- *Submit a short written report to the next meeting of the Standing Committee on the Bern Convention to be held in November 2009*.

Photo 8. *"On-the-spot appraisal 15-17 June 2009", with the appointed expert Eckhart Kuijken in the middle (his wife to the left) and Mrs. Carolina Lasén-Diaz from the Bern Convention Secretariat to the right.* Photo: Kjetil Bevanger.

1.7 Searches for electrocuted birds

On November 9-10 seven of the team members gathered on Smøla to search for dead birds within the electricity distribution system owned by NEAS (Nord-Møre Energiverk A/S). NINA had been supplied with a database from NEAS where all potential bird electrocution structures were identified. All together ca. 700 spots had been selected. Approximately 650 checkpoints were visited during the two day fieldwork; the remaining 50 will be visited in December. More than 120 electrocuted birds were recorded (Figure 1).

The background and the idea with this exercise were to collect facts on the mortality imposed to different bird species by the Smøla electricity grid system. This is particularly important regarding the possibility to develop a realistic WTE-population model able to predict long term population development. Moreover it could be useful information for the grid owner to have identified hazard structures that eventually may be removed to secure the safety for birds regarding electrocution hazard. Removal of electrocution traps would partly be a compensation for the wind-turbine induced mortality observed, e.g. to WTE.

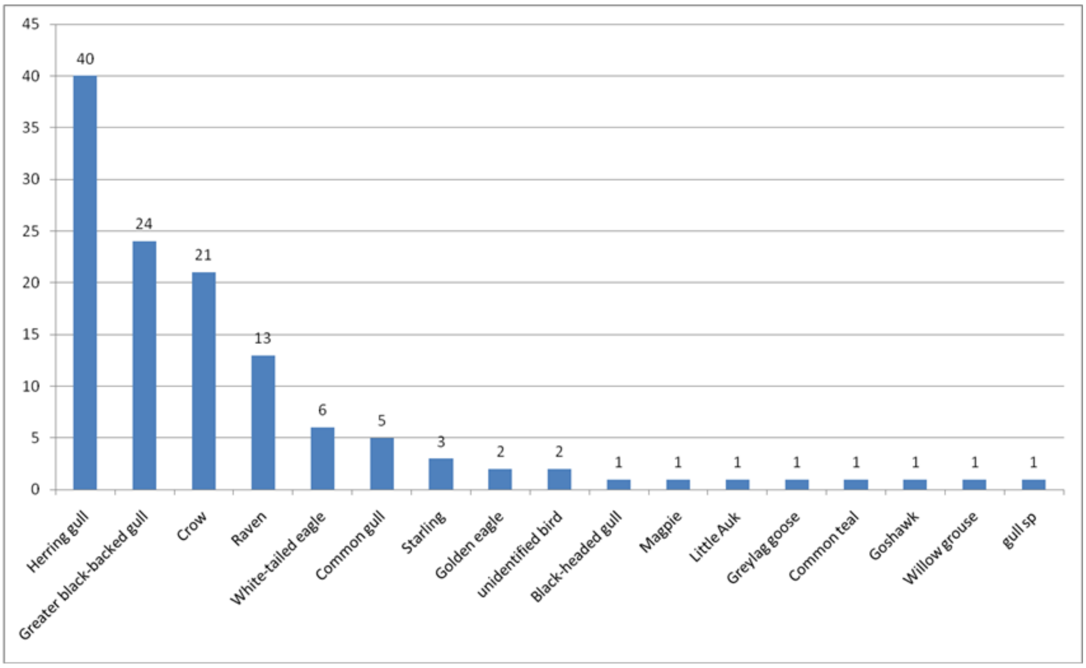


Figure 1. *Distribution of electrocuted birds recorded on Smøla 9-10 November in connection to approximately 650 check-points within the electricity grid system. Only birds found beneath power-line pylons are included. Some of the birds in the histogram may not have died from electrocution (ptarmigan, little auk, starlings, common teal, goose), as the remains may be a result of scavengers having used the pylon as a "dinner table".*

Photo 9. *Remains of an electrocuted WTE at the basement of a power-line pylon on Smøla recorded November 10 2009.* Photo: Kjetil Bevanger.

1.8 International conference on birds and wind power

BirdWind is approaching its finalisation; with 2010 as the last ordinary year where data collecting activities takes place. In 2011 the Annual Meeting is planned to be replaced by an international congress with focus on selected topics reflecting the project activities. Thus, NINA has initiated a planning process for a conference to be arranged in Trondheim on ecological impacts of wind-power generation in March/April 2011. A majority of the BirdWind-project results are supposed to be presented on the conference. A preliminary programme will be finalised in early spring 2010 and will possibly include sessions on

- Ecological Impact Assessments & pre- and post-construction studies
- Behavioural and spatial responses
- Population effects
- Collision risk modelling
- Tools and technology
- Mitigation and compensation

2 Subproject status

2.1 Mortality studies

Subproject responsibility: Ole Reitan

Objective: To conduct regular searches (once a week) for dead birds around selected wind turbines in the wind-power plant area as a basis for estimating overall and species-specific collision risks.

2.1.1 Activities and findings

Weekly searches with dogs are carried out throughout the year, from week 2 to 52. In general searches are conducted every 7 days (plus or minus one day). 25 ‘primary turbines’ are selected and searched together with one of two dogs. Of these 17 are defined as ‘outer turbines’, and 8 as ‘inner turbines’. The other turbines are searched using a dog in selected weeks in periods with high bird activity. In addition all turbine locations were searched visually on each search day. Visual searches were done during all car-driving along roads and turbine locations.

All recorded dead birds from the wind-turbine plant area, irrespective of cause of death or finding circumstances, are registered in a central database at NINA. This database includes 141 recording from 2003-2009 (per December 1 2009; Table 1). One specimen of the Northern bat is found below a turbine (44, August 2006).

Table 1. *Dead birds found within the Smøla wind-power plant area and birds recorded as collision victims at the wind turbines, until 1 December 2009.*

Species	Scientific name	Total bird recordings	Verified turbine victim
Willow ptarmigan	*Lagopus lagopus*	55	33
White-tailed eagle	*Haliaeetus albicilla*	28	28
Common snipe	*Gallinago gallinago*	11	11
Hooded crow	*Corvus cornix*	10	9
Gulls	*Larus spp.*	4	4
Golden plover	*Pluvialis apricaria*	4	4
Greylag goose	*Anser anser*	3	3
Grey heron	*Ardea cinerea*	3	3
Mallard	*Anas platyrhynchos*	2	2
Teal	*Anas crecca*	2	2
Whooper swan	*Cygnus cygnus*	1	1
Shoveler	*Anas clypeata*	1	1
Red-breasted merganser	*Mergus serrator*	1	1
Northern fulmar	*Fulmarus glacialis*	1	1
Merlin	*Falco columbarius*	1	1
Redshank	*Tringa totanus*	1	1
Kittiwake	*Rissa tridactyla*	1	1
Little Auk	*Alle alle*	1	1
Meadow pipit	*Anthus pratensis*	1	1
Northern wheatear	*Oenanthe oenanthe*	1	1
Fieldfare	*Turdus pilaris*	1	1
Parrot crossbill	*Loxia pytyopsittacus*	1	1
White-tailed eagle div.		3	0
Bird indet.		4	3
Birds total		141	114

In 2009 (up to December 1) 31 specimens of at least 8 species have been recorded. The most frequent victims were willow ptarmigan and white-tailed eagle with 10 and 7 carcasses, respectively. Of waders 3 common snipes were recorded. Five carcasses were recorded of hooded crow (1 old) and single carcasses of parrot crossbill, northern wheatear, teal and mallard. Some records from earlier years have been revised as collision victims or not (Figure 2, Table 2).

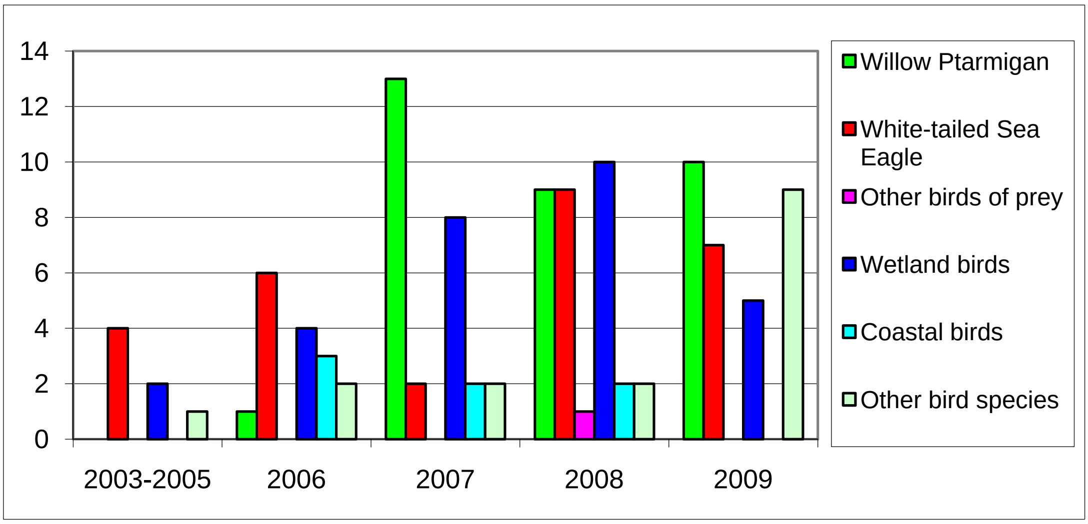


Figure 2. *Bird collision victims recorded within the Smøla Wind-Power Plant. "Other birds of prey" is a merlin; "wetland birds" are waders, ducks, geese, swans and grey heron; "coastal birds" are gulls, auks, and fulmar and "other bird species" are passerines.*

Table 2. *Birds recorded each year as collision victims within the wind-power plant area on Smøla (per 1 December 2009). For total number and scientific names, see Table 1.*

Species	2003-2005	2006	2007	2008	2009
Willow ptarmigan		1	13	9	10
White-tailed eagle	4	6	2	9	7
Common snipe		1	3	4	3
Hooded crow	1	1		2	5
Gulls		3		1	
Golden plover			2	2	
Greylag goose	1			2	
Grey heron	1	1		1	
Mallard			1		1
Teal			1		1
Whooper swan		1			
Shoveler		1			
Red-breasted merganser			1		
Northern fulmar			1		
Merlin				1	
Redshank				1	
Kittiwake				1	
Little Auk			1		
Meadow pipit			1		
Northern wheatear					1
Fieldfare		1			
Parrot crossbill					1
White-tailed eagle div.					
Bird indet.			1		2
Birds total	7	16	27	33	31

2.1.2 Scavenger removal and search bias testing

As in previous years, the scavenger removal bias has been estimated based on artificially carcasses placed at randomly selected wind turbines, in randomly selected distances and compass directions from the turbines (week 31). In general, approximately 10% of the dead birds have disappeared every week, but bird remains have remained for quite some time. There were large differences between the two experiments in 2009 (Table 3).

In the same experiment the search efficiency for the dogs were studied. Search efficiency was poor in the first week in 2009, approximately 20 %. In the second week it varied between 33-50%.

In autumn 2009 an experiment with cameras at bird carcasses was initiated in order to investigate both the scavenger removal bias and the scavenging species. There has been little activity at the carcasses, 3 of the first 4 carcasses were not scavenged in four weeks. The last was removed and hoarded outside the searched area in the fourth week.

Table 3. *Carcasses remaining within 100m from a wind turbine (the 2009-experiment). N=10 in each experiment. "Remaining" means that the object is found within the searched area (r= 100m). "Not moved" means that the object was at the same GPS-position as at the start of the experiment.*

Experiment	Start	Remaining week 1	Remaining week 2	Not moved week 1	Not moved week 2
2009-1	29 July 2009	100%	90%	80%	60%
2009-2	29 July 2009	60%	60%	40%	40%

2.2 Willow ptarmigan

Subproject responsibility: Hans Chr. Pedersen

Objectives: Study direct and indirect effects of wind turbines on willow ptarmigan behaviour, habitat selection, reproduction and survival in areas where wind-power plants are established or planned.

In connection to the Environmental Impact Assessment before the development of the Smøla Wind-Power Plant, the willow ptarmigan population was censused during May and August in 1999 (Follestad et al. 1999). An autumn census was continued by the landowners also in some years during 2000-2004. From 2005, an autumn census was carried out as part of a larger countrywide census programme (e.g. Solvang et al. 2005). From spring 2007 the willow ptarmigan population has been censused spring and autumn in the wind-power plant area and in an adjacent control area outside the plant area. The census method used is line transects applying the programme DISTANCE. The census gives information on density and reproduction (chick production) in both areas. In August 2007 censuses of willow ptarmigan were also carried out on the adjacent island Hitra, within the Eldsfjellet Wind-Power Plant, and in the control area Skårfjellet. In both areas suitable willow ptarmigan habitat are very limited, and a modified version of DISTANCE was therefore used.

2.2.1 Activities and findings

Also in 2009 a census has been carried out in spring and autumn on Smøla and Hitra. In 2009 the same transect lines as used in 2008 were censused.

The preliminary results do not indicate any obvious differences between the two areas, but autumn density in the wind-power plant area seems to be more stable compared to the control area (Figure 3). Interestingly the seemingly higher density within the wind-power plant area in autumn seems to be evened out in spring each year, so also in spring 2009 (Figure 3).

Annual chick production is one of the most important factors affecting autumn population density in willow ptarmigan. On Smøla the chick production has not been significantly different in the two areas from 2005-2007 and cannot explain the increased difference in density between the two areas (Figure 4). However, in August 2008 the chick production in the wind-power plant area was 6.4 chicks/female and only 2.7 in the control area, contributing substantially to the difference in density. This was also the situation in autumn 2009, when the wind-power plant area and the control area had a chick production of 4.6 chicks/female and 2.9 chicks/female, respectively.

On Hitra, the autumn density increased in 2009 from the low year of 2008. The increase occurred both in the wind-power plant area and the control area, and no difference was found between these two areas (Figure 5).

To collect data on habitat selection, movements, collision risks, survival of eggs, chicks and adults and general population dynamic parameters, willow ptarmigan have been radio-tagged in 2008-2009. We have used traditional VHF-transmitters with mortality switch, necklace mount, 12 g Holohill transmitters lasting for approximately 24 months. Due to low population density and only occasional snow cover, a method using strong lights, dipnet and car has been used to catch birds. This method can only be used during winter at nights without any moonlight. It is very time consuming, but it works. However, the number of individuals being caught is only 24 (13 males and 11 females) in two years.

All birds are caught inside the wind-power plant area (Figure 6). No trapping has been carried out in the control area, mainly due to missing roads. The birds have been radio-tracked at irregular intervals and almost all birds, when found, have been located within the wind-power plant area, not far from where they were caught.

Except from one bird, where an exhausted battery was the likely reason for a missing signal, no radio-tagged ptarmigan have been lost. In early November 2009, 6 radio-tagged ptarmigans were found in the area, which means that 17 birds have died since the radio-tagging started in January 2008. Most birds die during winter, from December throughout March. Although a thorough analysis of mortality causes has yet not been carried out, most birds seem to be killed by avian predators and to a lesser extent by colliding with wind turbines.

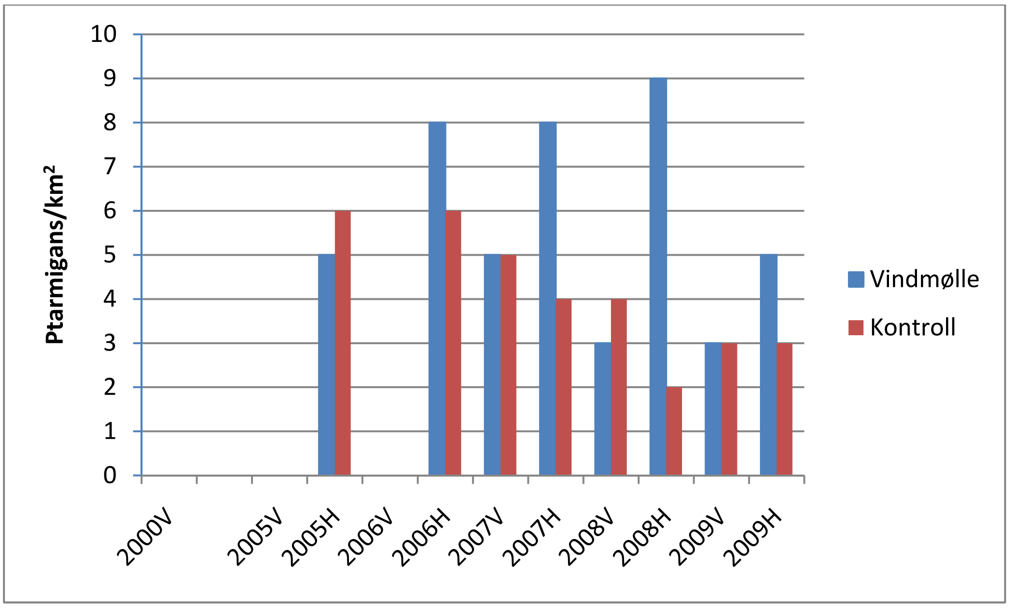


Figure 3. *Population density of willow ptarmigan (birds/km^2) in spring (V) and autumn (H) in the wind-power plant area (blue) and control area (red) in 2007-2009 on Smøla.*

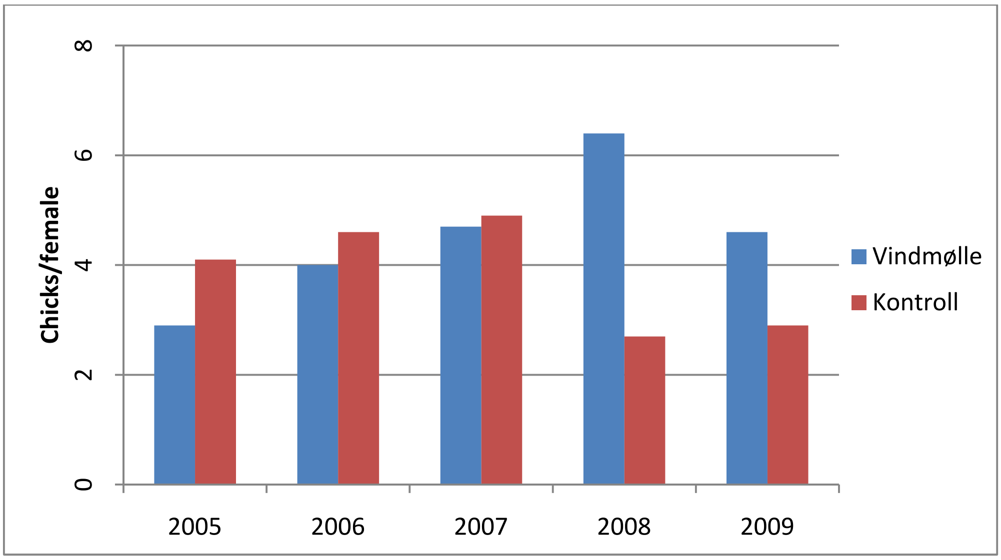


Figure 4. *Chick production expressed as number of chicks per female in August in the wind-power plant area (blue) and control area (red) during 2005-2009 on Smøla*.

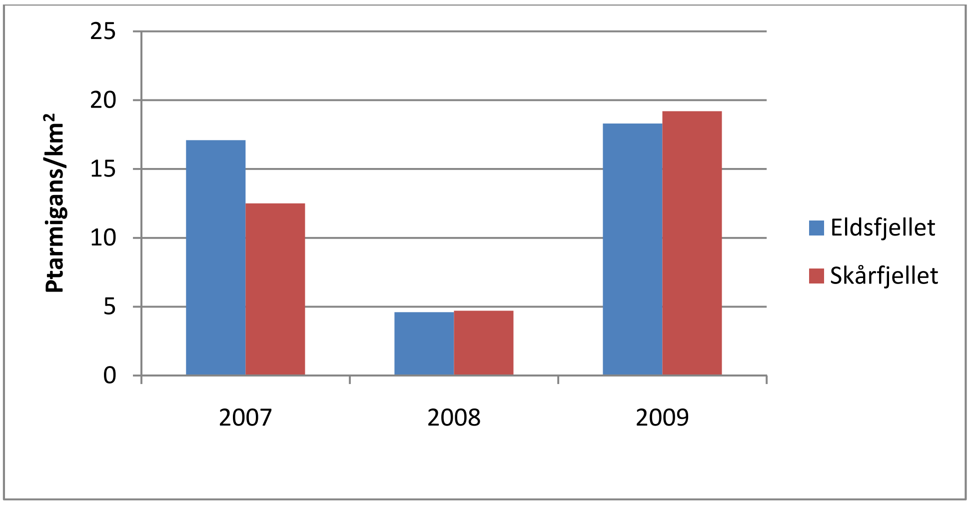


Figure 5. *Population density of willow ptarmigan (birds/km^2) in August in the wind-power plant area (blue) and control area (red) during in 2007-2009 on Hitra.*

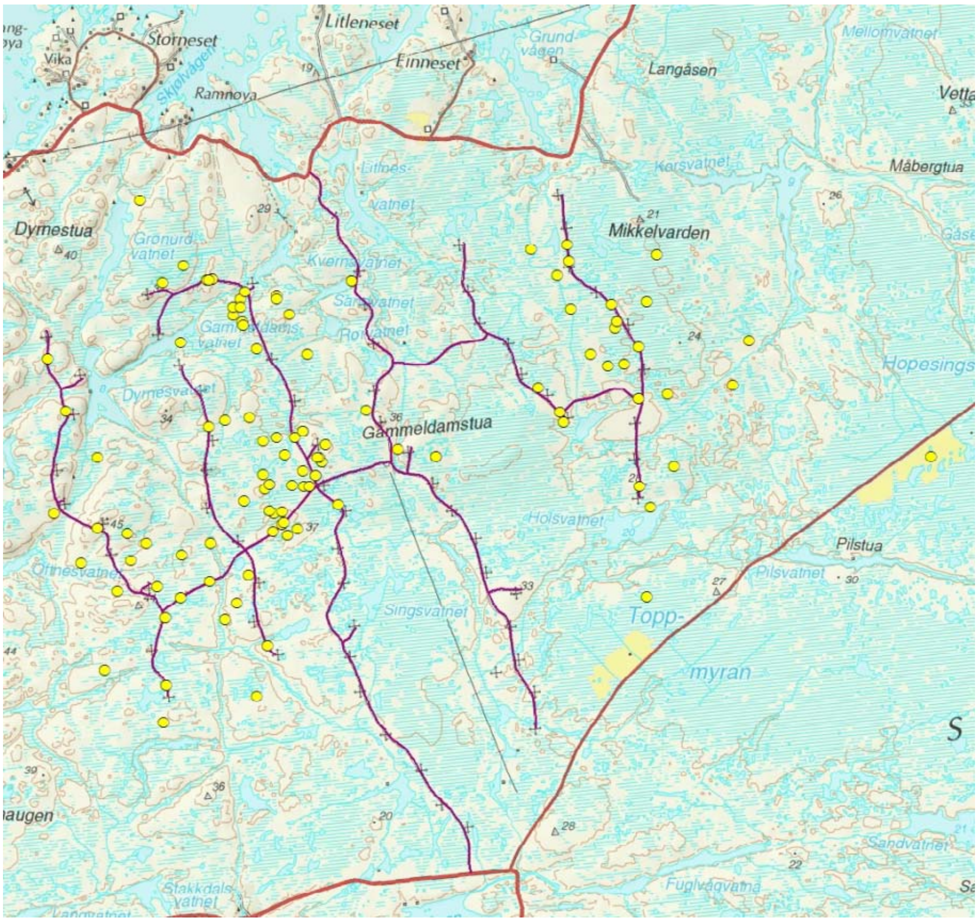


Figure 6. *Locations of radio-tagged willow ptarmigan caught in the wind-power plant area on Smøla.*

2.3 Breeding waders and smaller passerines

Subproject responsibility: Duncan Halley

Objectives: To survey breeding populations of waders and small passerines in relation to wind turbines and assess any evidence for effects on bird distribution in relation to wind turbines.

The activities on this project this year have focused on the EIA-activities on Hitra in connection to the planned extension of the existing power plant (Hitra I), i.e. a Hitra II Wind-Power Plant (cf. Bevanger et al. 2009).

2.3.1 Breeding birds in the proposed Hitra II power-plant area

2.3.1.1 Methods

Standard line-transect methods (Rosenstock et al. 2002, Burnham et al. 1980, Buckland et al. 1993) were used in the plan area. 12 transects were defined in an east-west orientation, each 1km in length except for LVN1 (921m) and LVN2 (919m) covering all the larger areas in the development plan as then defined (Figure 7). The exact length of each transect was taken into account in all subsequent analysis. Data was collected from each transect on three occasions in the period 22nd May-9th July 2009, this being the breeding season for most of the bird species expected in the area and the time of year in which birds are normally easiest to observe given singing, territorial, and warning call behaviours which are commonest at that time. Individuals were registered in a band from 0-100m north and south of the transect line. The distance to the observer was measured using laser binocular rangefinders, and the DISTANCE programme used to estimate detection probability at various distances (Buckland et al. 2001).

Densities of birds can then be calculated from this data using DISTANCE, though in this case (see below) densities, especially on the mountain plateau, were often too low for estimates to be calculable. All ponds and lakes on the periphery of the plan area were checked for waterfowl on every visit. Outside structured observations, all casual records of less common birds, and the location of any nests found, were noted by all members of the project team.

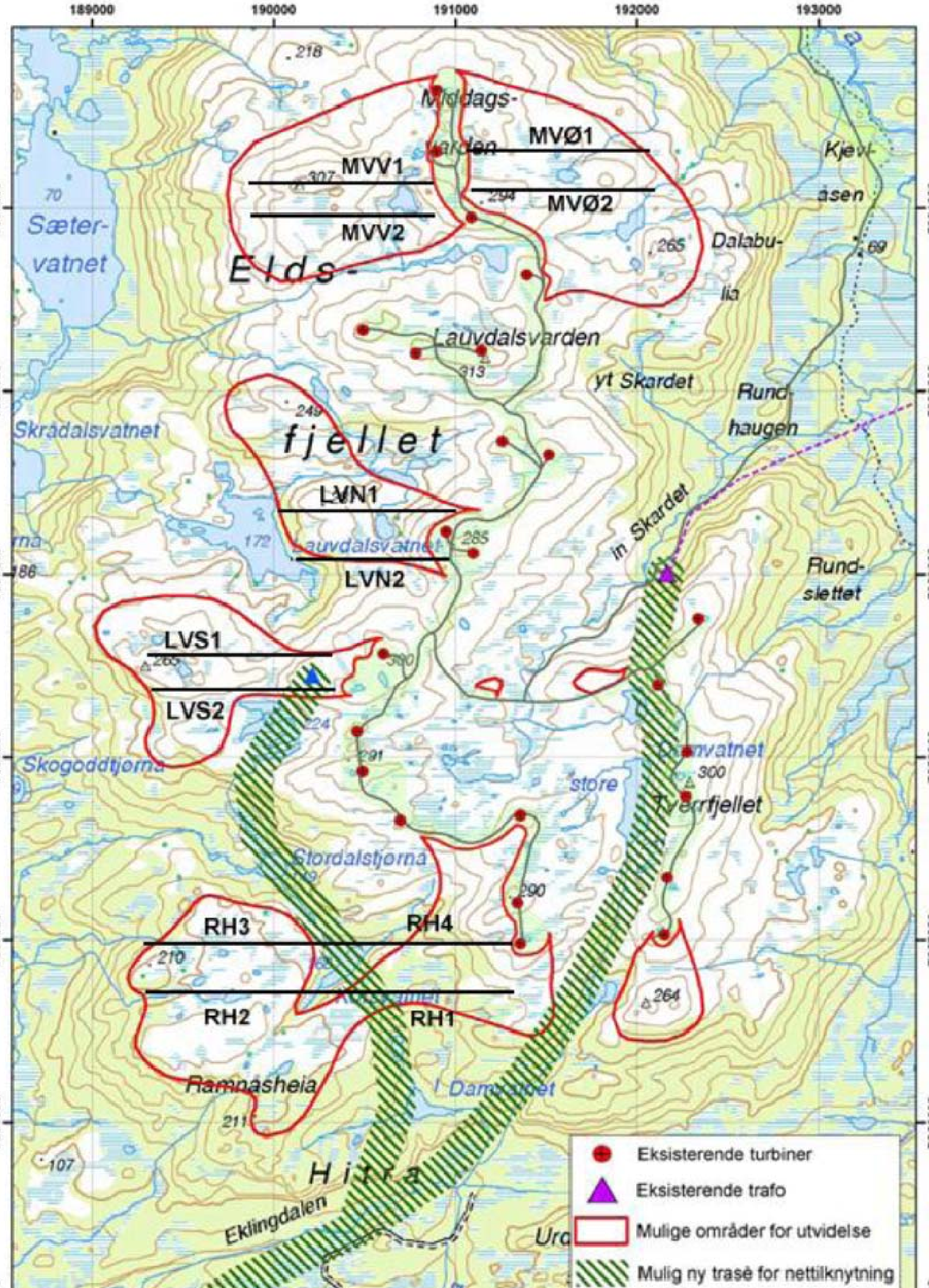


Figure 7. *Location of transect lines for small birds and waders in the plan area for the Hitra II Wind-Power Plant. Transects were 100m in length, with the exceptions of LVN1921m) and LVN2 (919m).*

2.3.1.2 Results

The number of birds of the various species observed is presented in Table 4.

Tabell 4. *Total number of birds of each species observed during transect counts of the plan area for the Hitra II Wind-Power Plant.*

Species	Total observations
Meadow pipit / Heipiplerke	46
Wheatear/Steinskvett	25
Chaffinch/Bokfink	20
Chiffchaff/Granmeis	16
Great tit/Kjøttmeis	9
Golden plover/Heilo	8
Blackbird/Svarttrost	8
Chiffchaff/Gransanger	7
Mallard/Stokkand	6
Willow warbler/Løvsanger	5
Song thrush/Måltrost	4
Goldeneye/Kvinand	3
Redshank/Rødstilk	3
Redstart/Rødstjert	3
Twite/Bergirisk	2
Redpoll/Gråsisik	2
Dunnock/Jernspurv	2
Redwing/Rødvingetrost	2
Common sandpiper/Strandsnipe	2
Coal tit/Svartmeis	2
Willow ptarmigan/Lirype	1
Raven/Ravn	1
Woodcock/Rugde	1
Robin/Rødstrupe	1
Kestrel/Tårnfalk	1

The results indicate a clear difference in species diversity and densities between the mountain plateau on Eldsfjell (all transects except RH1-4) and in the Korsvatnet – Ramnåsheia area (RH1-4). The density of birds on the Eldsfjell plateau was low and consisted mainly of three species, meadow pipit (heipiplerke), wheatear (steinskvett), and golden plover (heilo). Willow ptarmigan and redshank were also observed. The only observations of other species in the Eldsfjell area were in or near small cliffs with scrub at the edge of the area, two twite (bergirisk) and two kes-trels (tårnfalk) (one observed outside structured observations); both possibly breeding pairs.

Casual observations of grey-headed woodpecker (gråspett) (1) and ring ouzel (ringtrost) (1) were noted outwith the tranects; the former close to the southernmost existing turbine, and the latter (an adult male) in the eastern part of Middagsvarden. A meadow pipit nest with four eggs was found ca. 10m from the base of the same turbine. To summarise, the mountain plaeau of Eldsfjel-let appears relatively impoverished both in species and in numbers of small birds and waders, which is not surprising considering the infertile underlying rock (granite), the highly exposed loca-tion, and the sparse soil coverage outwith patches of mire.

The Korsvatnet-Ramnåsheia area in the southwest lies lower than Eldsfjellet; this part of the plan area is dominated by relatively fertile mixed pine/birch woodland in natural succession, with con-siderably better developed soils than on the mountain plateau. Trees on the top of Ramnåsheia are more sparse and patchy, and the trees more bushy in form, but nevertheless support a num-ber of typical woodland species along with species associated with more open terrain, especially where there are patches of open mire. This area has a considerably higher density of birds, as well as a greater diversity of species. Chiffchaff (gransanger), willow warbler (løvsanger), chaffinch (bokfink), song thrush (måltrost), redwing (rødvingtrost), blackbird (svarttrost), willow tit (granmeis), great tit (kjøttmeis), siskin (grønsisik), robin (rødstrupe), and dunnock (jernspurv) were all common. Coal tit (svartmeis), redpoll (gråsisik), redstart (rødstjert), raven (ravn), lirype (willow ptarmigan), woodcock (rugde), and common sandpiper (strandsnipe) were also observed. Woodpeckers are difficult to register through direct observations, but marks on trees show that woodpecker species are also common. Eight grey-headed woodpeckers (gråspett) were observed outwith transect observations in woodland area on the southwest and western flanks of the Eldsfjellet massif spring-summer of 2009; further data (M. Pearson pers. comm.) shows a dense (for the species) concentration of grey-headed woodpeckers (gråspett), which are red-listed, in this area, which includes Ramnåsheia and the area adjacent to the top 265m southwest of Lauvdalsvatnet (Figure 8).

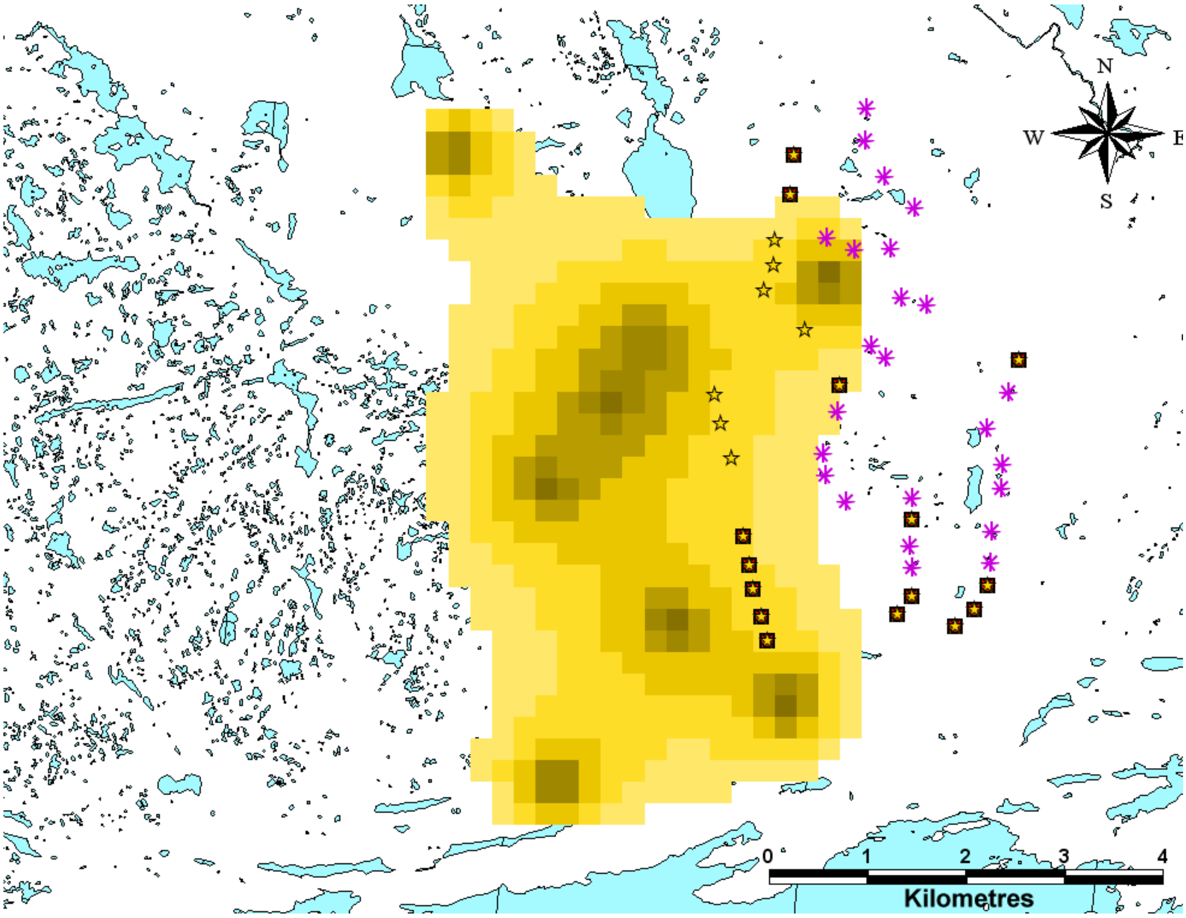


Figure 8 *Relative density of grey-headed woodpecker (gråspett) in the Ramnåsheia area. Small stars indicate existing wind turbines, proposed turbines under Alternative A as squares, and under alternative B as yellow stars. Darker colours indicate increasing densities (white = area not assessed). Data: M. Pearson (pers. comm.).*

Waterfowl are not common on lakes or ponds either in the plan area, or in the valleys between ridges of the south-western Eldsfjellet massif. A female goldeneye (kvinand) with five ducklings was seen on Lauvdalsvatnet, and a mallard (stokkand) female with five ducklings on a pond on the top of Ramnåsheia. Two female goldeneyes (kvinand) were seen on Korsvatnet. Diver species (lomarter) did apparently not breed within or adjacent to the plan area in 2009, although a black-throated diver (storlom) was seen on Skogoddvatnet ca. 1km west of the plan area in spring, and breeding on lakes or ponds on the edge of the plan area cannot be excluded in the future. Data from Smøla (Halley & Hopshaug 2007) indicate that breeding in the wind-power plant area after construction is unlikely. The red-listed whooper swan (sangsvane) has been observed on on Skogoddvatnet and Tømmeråstjønna, ca. 2km northwest of the plan area (M. Pearson pers. comm.).

2.3.2 Analysis of densities using DISTANCE

The DISTANCE-programme calculates the probability that a bird will be detected at a given distance from a transect (Buckland et al. 2001). From this a model is constructed to estimate the actual densities of birds in the area. Figure 9 shows the calculated chance of detection, based on the data collected in this study.

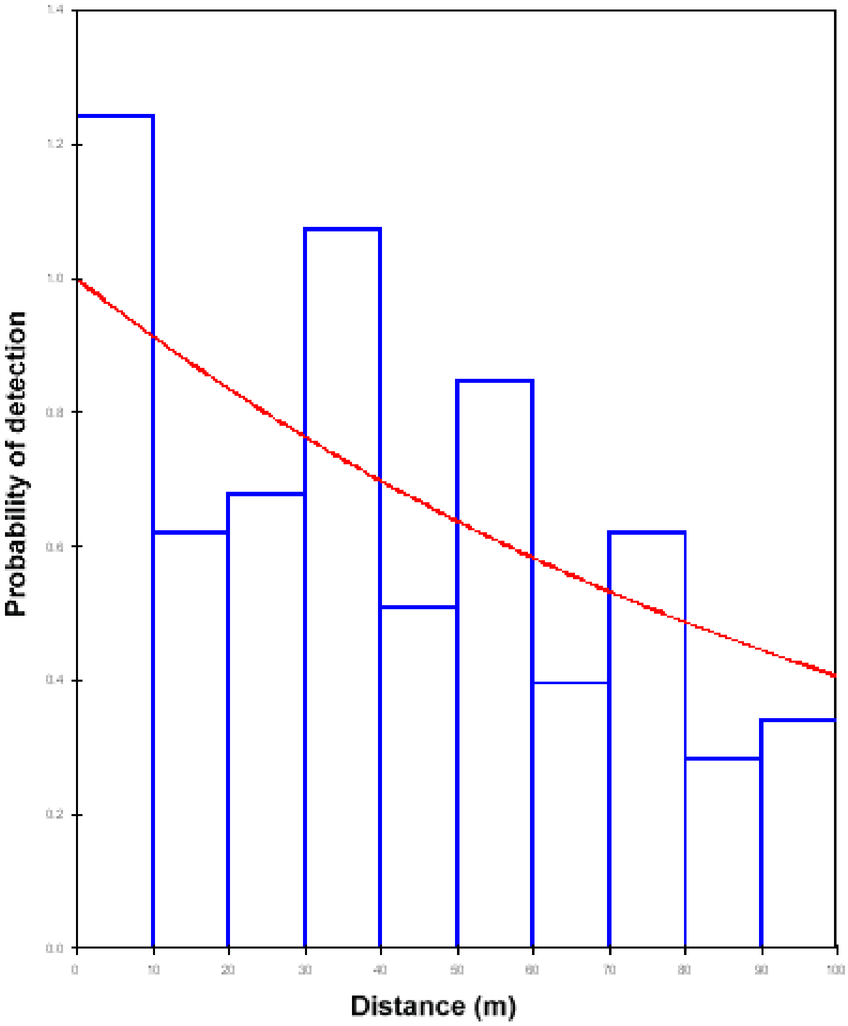


Figure 9. *Detection probabilities for all birds and all transects combined to a distance of 100m from the transect line (see Figure 7).*

From the data, an overall density of 36.5 birds/km^2 (+/-8.56 SE) is calculated. This is a relatively low number, but conceals a large difference in densities between the plan areas on Eldsfjell and Ramnåsheia (Table 5).

Table 5. *Density of small birds and waders in various parts of the plan area (the 95% confidence interval of the LVN transects is extremely high due to the very low number of birds (8) recorded in the area.*

Transect	Birds/km^2	SE	% coefficient variation	95% confidence interval (lower)	95% confidence interval (upper)
MVØ1-2	28.3	6.7	23.7	16.9	47.4
MVV1-2	40.0	3.4	8.6	33.49	47.9
LVN1-2	16.3	9.6	58.6	0.1	4319.9
LVS1-2	25.0	5.0	20.0	15.8	40,0
RH1-4	163.3	14.7	9.0	136.6	195.4

The mountain plateau areas of Eldsfjellet (all transects except RH1-4) have a bird density of between 16.3 and 40 birds/km^2 while the Ramnåsheia area (RH1-4) has a density of 163.3 birds/km^2, i.e. between 4 and 10 times higher. The diversity of species was also higher, with 21 species registered in the four Ramnåsheia transects compared to 10 in the eight transects on Eldsfjellet (combined).

The density of individual species in the various areas on Eldsfjellet was without exception too low to calculate density estimates. Density estimates for the commonest species in the Ramnåsheia area are shown in Table 6.

Table 6. *Densities of the most common small bird species in the Ramnåsheia area.*

Species	Birds/km^2	SE	% coefficient of variation	95% confidence interval (lower)	95% confidence interval (higher)
Chaffinch/Bokfink	32.6	9.8	30.0	17.8	59.8
Willow tit/Granmeis	40.1	12.6	31.3	20.9	77.1
Meadow Pipit/Heipiplerke	25.1	9.3	37.0	10.9	58.0
Blackbird/Svarttrost	12.5	2.4	19.2	8.6	18.4

2.3.3 Summary

Small bird and wader populations within the Eldsfjell plateau part of the plan area consist of low density and low diversity populations of common small passerines and waders. The danger of negative consequences for the species apart from at a very local scale is consequently low. Breeding of meadow pipits (heipiplerke) was confirmed within 15m of an existing turbine. Two of the species registered on Eldsfjell are red listed (wheatear (steinskvett) (NT) and twite (bergirisk) (NT)). The twite is also a species of special responsibility ("ansvarsart") for Norway. Despite the decline in population (which is the reason for the species being placed on the red list), the wheatear is nevertheless a common bird in Norway, and one of the commonest of all in mountain areas. It is not expected that further development of wind turbines at this site would be of significance for the national distribution of the species. The twite was uncommon in the plan area (1 observation, 2 individuals), probably because of a lack of suitable habitat locally.

Both species diversity and densities were considerably higher in the Plan area around Ramnåsheia. This is because the area is at a lower elevation and is to a large extent wooded; even the top of Ramnåsheia is to a significant degree patchily covered with bushy or dwarfed trees (due to the exposed location). This area must therefore be considered separately from Eldsfjellet. Most species found here are common in Norway, with the exception of the red-listed grey-headed woodpecker (gråspett) (NT), which has a relatively high density population in some of the woodland within and adjacent to the plan area. The risk of collisions with turbines and power lines, and/or population declines due to habitat loss/fragmentation and disturbance related to turbine maintenance and operation, is probably higher in this area given the higher absolute density of birds of various species.

Results from transects on Eldsfjellet can with appropriate caution be extrapolated to other areas on the mountain plateau above the tree line, and data from the Ramnåsheia area can be considered broadly representative of similar areas on the flanks of Eldsfjellet. Taken together, the data suggests there is little risk of significant negative consequences to the species studied if a Hitra II development is built on Eldsfjellet. In lower lying areas on the edge of the massif, such as Ramnåsheia and similar areas to the north, risks associated with development are somewhat higher, given the denser and more diverse bird fauna. This includes possible effects on the grey-headed woodpecker (gråspett) population; other small bird and wader species known to occur in the area are relatively common.

The low densities of birds on Eldsfjellet in particular mean that the potential of this area for before-and-after studies of bird populations is very limited, as changes in densities would be difficult to detect.

2.4 White-tailed eagle (WTE)

2.4.1 Telemetry studies and risk assessments

Subproject responsibility: Torgeir Nygård

2.4.1.1 Material

Since 2003, 50 nestlings of white-tailed eagle are equipped with satellite transmitters, of the following types:

- 33 Argos/GPS solar Microwave Telemetry 70 g
- 9 Argos/GPS battery Microwave Telemetry LC4
- 8 GPS battery archival Televilt Posrec (obtained data from only 3)

In total, 45 of these have given data. Since 2005, only the Microwave transmitters have been used. Up until 1st of November 2009, 79,304 GPS positions have been obtained from these 45 working transmitters, ranging from 44 to 5,411 positions per transmitter; 41,588 of these positions came from Smøla.

In 2009, eight nestling white-tailed eagles were tagged, six with solar-powered and two with battery-powered transmitters. One was tagged within the wind-power plant, the others in close vicinity of it. The solar-powered transmitters used in 2009 were programmed to give one position per hour during summer in order to have finer resolution of movements for risk modelling purposes. During winter, much less frequent downloading is scheduled, due low light and poor battery-charging. The tagging was done with permission from the National Animal Research Authority of Norway.

Six of the transmitters are still giving data from live birds, one satellite-tagged bird was killed by a turbine ca. 24th of September 2009, and one has gone silent and has not been recovered. By the end of October 2009, 16 birds still gave GPS-positions.

Four out of the 45 satellite-tagged juvenile eagles during 2003-2009 have been killed by wind turbines on Smøla, during their first year of life, contributing to 9% added first-year mortality of the tagged population of young.

The results from Smøla are unique in its kind, nowhere else have so detailed information been gathered on the behaviour of eagles breeding in close vicinity of a wind-power plant. All GPS positions from all years are shown in Figure 10.

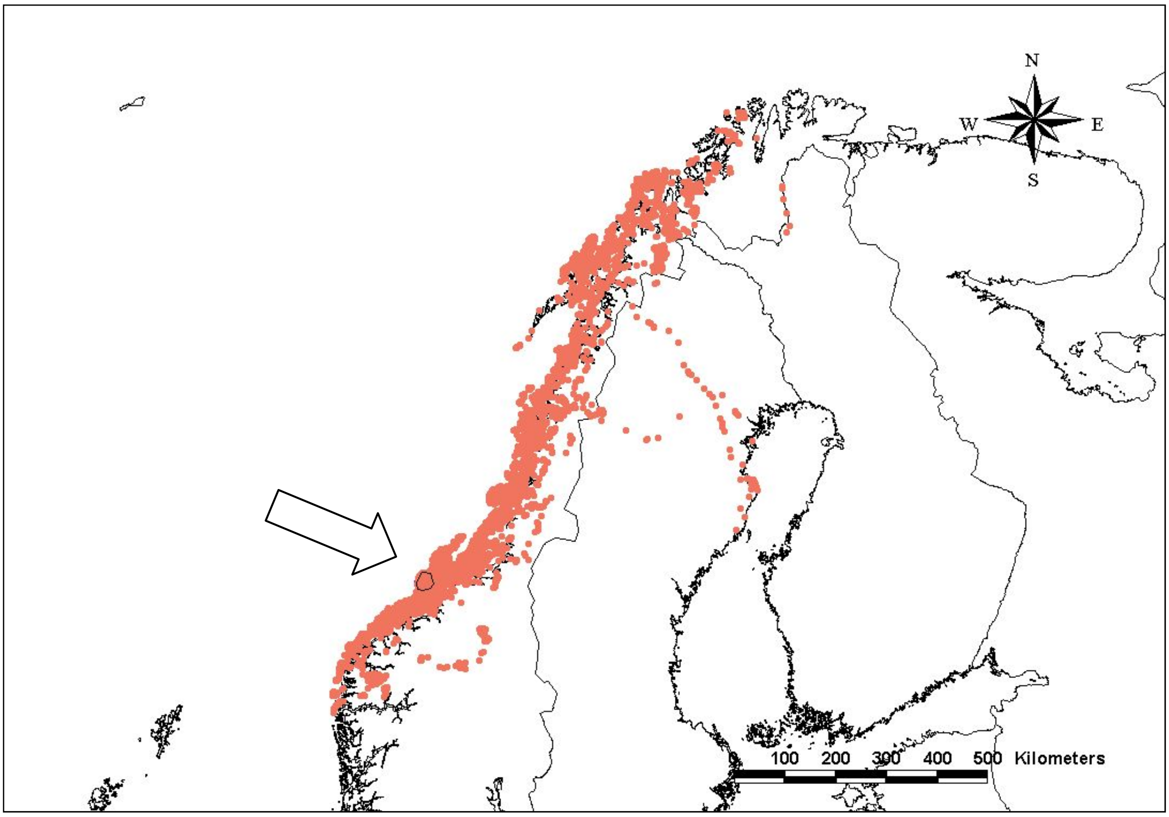


Figure 10. *All GPS positions from all years 2003-2009 (n = 25 males and 20 females). The arrow indicates the tagging site (Smøla).*

2.4.1.2 Movements

A regular seasonal pattern of movements emerges when plotting distance from natal site against month (Figure 11). Both sexes stay fairly close in the natal area during their first winter, and disperse during their first summer. They then return in their second autumn to the area close to the natal site. This pattern is repeated in their third and fourth year. In general, females disperse further than males, especially in their third and fourth year. Most movements are to the north, but there are some shorter movements to the south (Figure 12). The fact that juveniles from Smøla use almost the entire Norwegian coastline may have implications for site selection of future wind-power plants along the Norwegian coast.

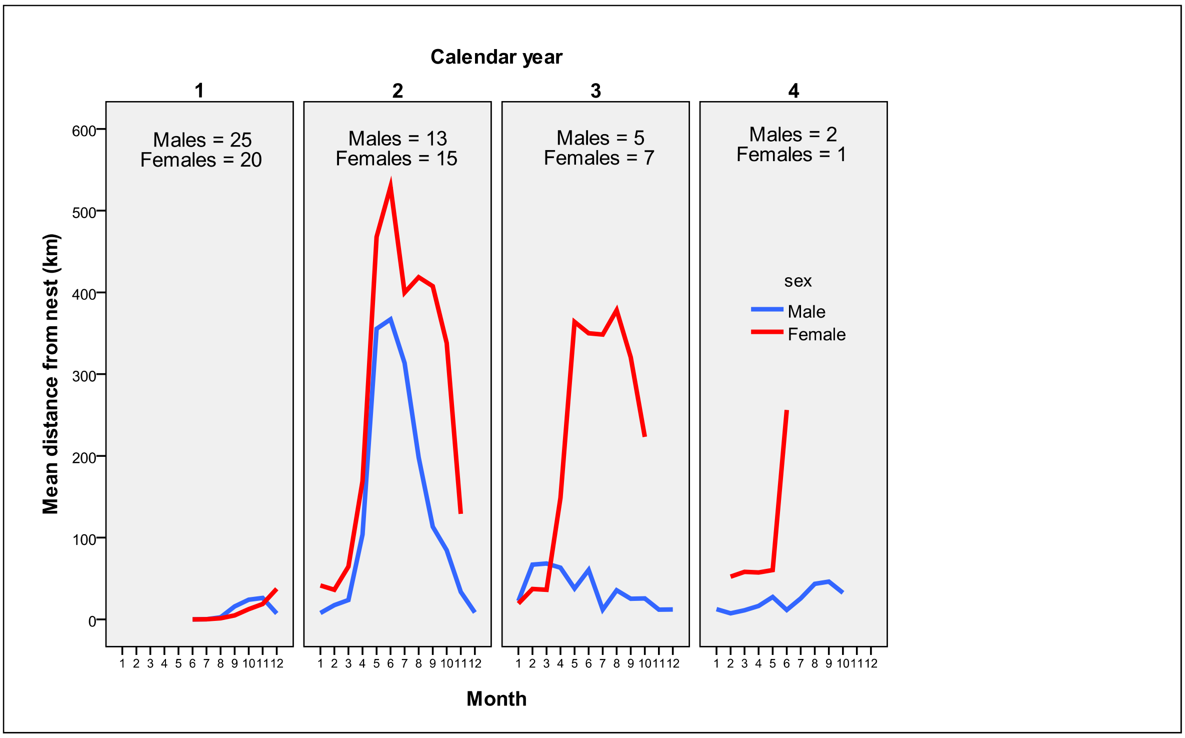


Figure 11. *Mean distance from the nest by month and calendar year of juvenile white-tailed eagles satellite-tagged on Smøla 2002-2009.*

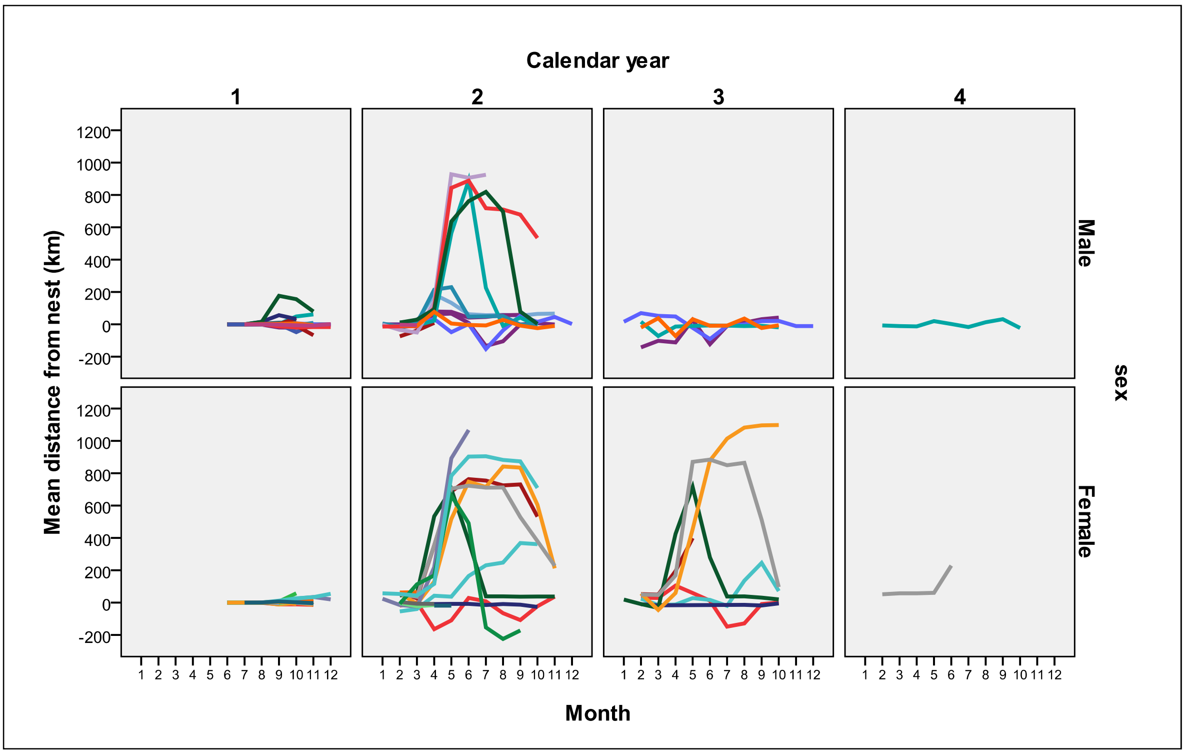


Figure 12. *Mean distance from nest by month and calendar year of individual juvenile white-tailed eagles satellite-tagged on Smøla. Positive values indicate northward movements, negative values southward.*

It is clear from the data that young eagles of local origin will be primarily on Smøla during the first autumn (Figure 13), winter (Figure 14) and in the following early spring. Autumn and early spring are the time of the year when all the mortalities of tagged juveniles associated with wind turbines have occurred (two during first autumn and two during the following spring).

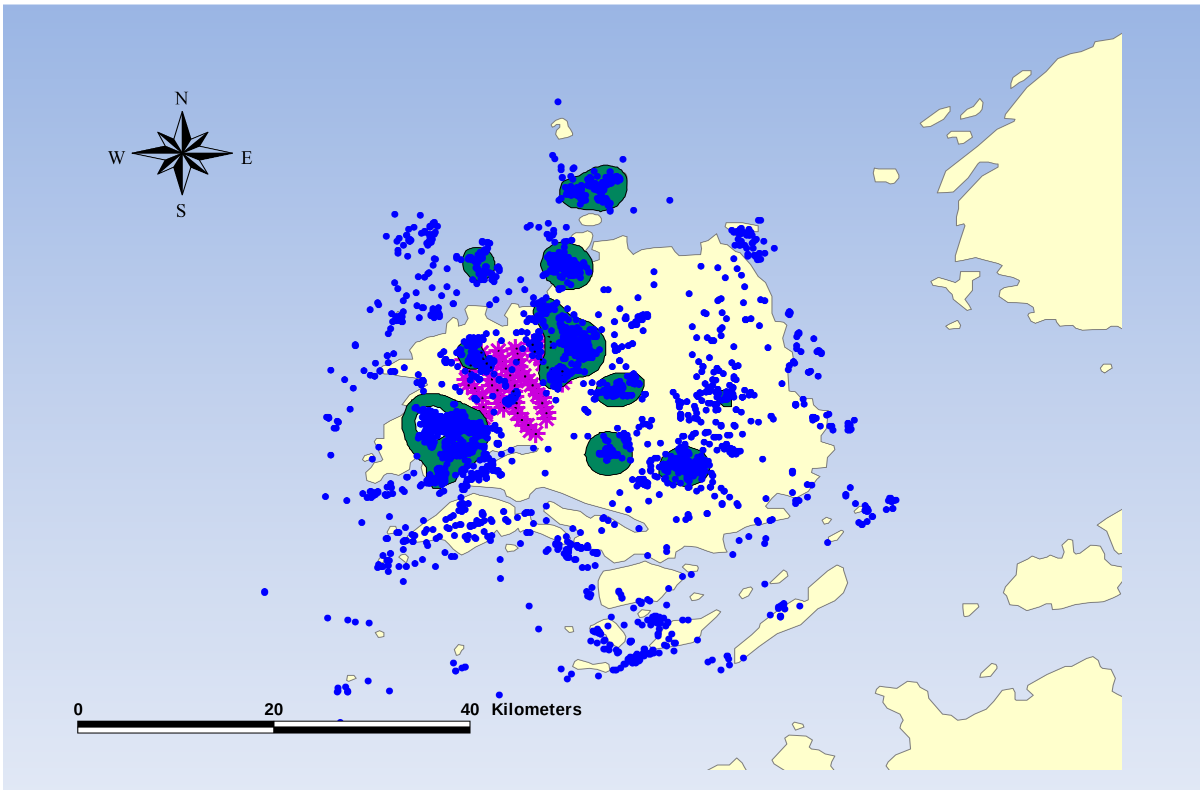


Figure 13. *The positions of satellite-tagged juvenile white-taailed eagles during August - September during their first calendar year. 95% (dark green) and 50% (light blue) kernel probability contours are shown.*

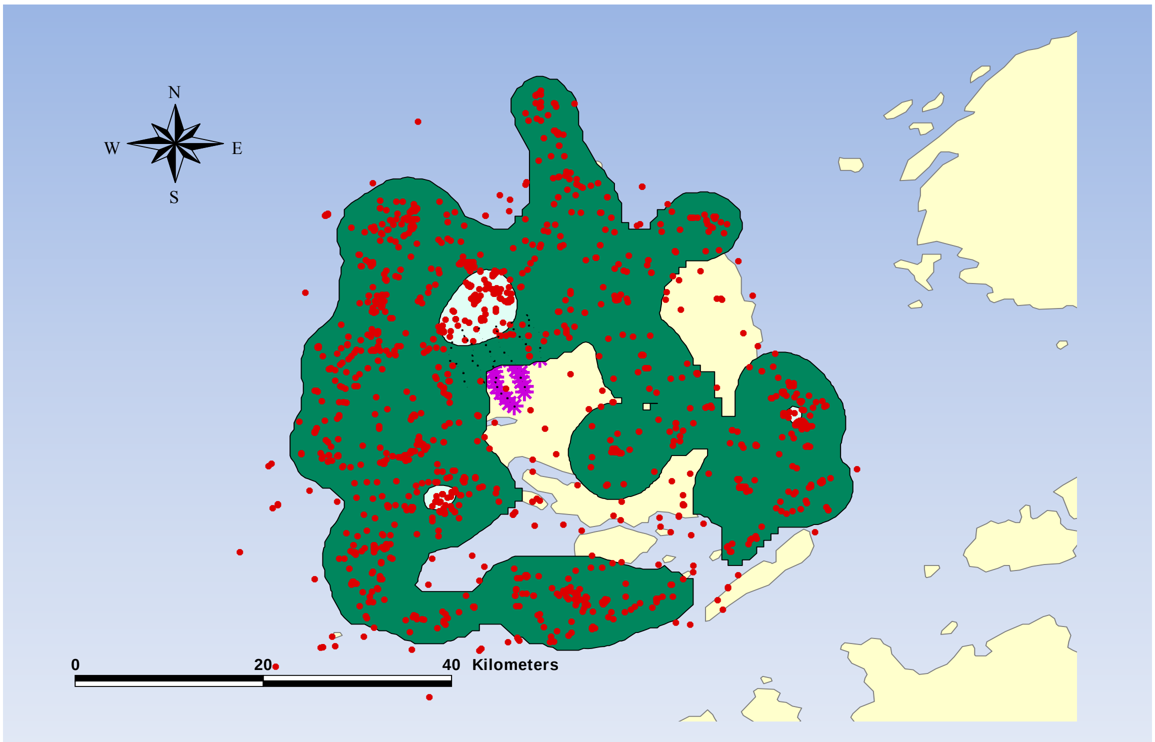


Figure 14. *The positions of satellite-tagged juvenile white-tailed eagles during January - March during their second calendar year. 95% (dark green) and 50% (light blue) kernel probability contours are shown. Some individuals were not on Smøla and are not shown.*

During their first years of life, the young birds seem to spend most of their time in the Smøla area, with the notable exception during the first summer, when most birds of both sexes will leave Smøla. Males will, overall, spend more time on Smøla than females. The relative occurrence of birds giving signals from Smøla *vs.* outside Smøla is shown in Figure 15.

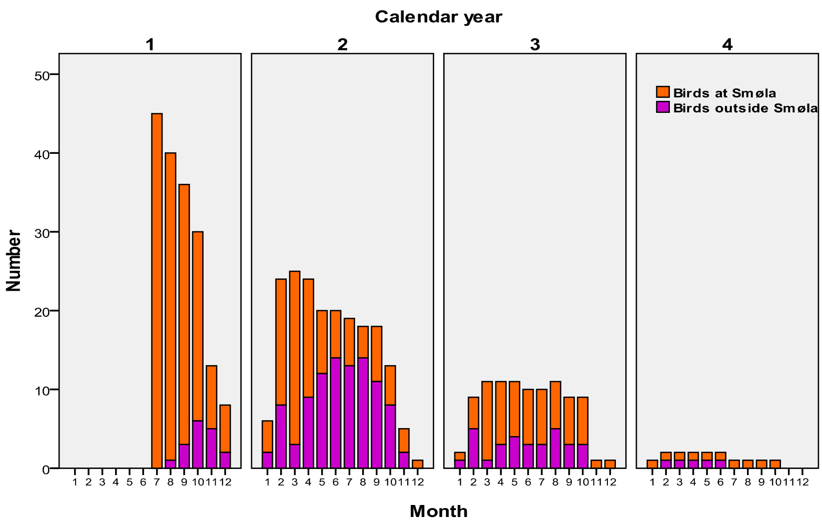


Figure 15. *The number of juvenile white-tailed eagles tagged on Smøla giving signals from the island* vs. *elsewhere. The drop in numbers during winter is due to poor light conditions, which will prevent solar-powered transmitters from sending signals.*

2.4.1.3 Use of the wind-farm area by juvenile birds

In quite a few cases, tagged juvenile birds have apparently been in the rotor-swept zone of the turbines (Figure 16). As most birds spend most of their time on the ground, it is probable that the birds were sitting underneath the rotor-swept area in most of these cases, and therefore escaped from being hit. Still, the risk of a wrong move is greater here than elsewhere.

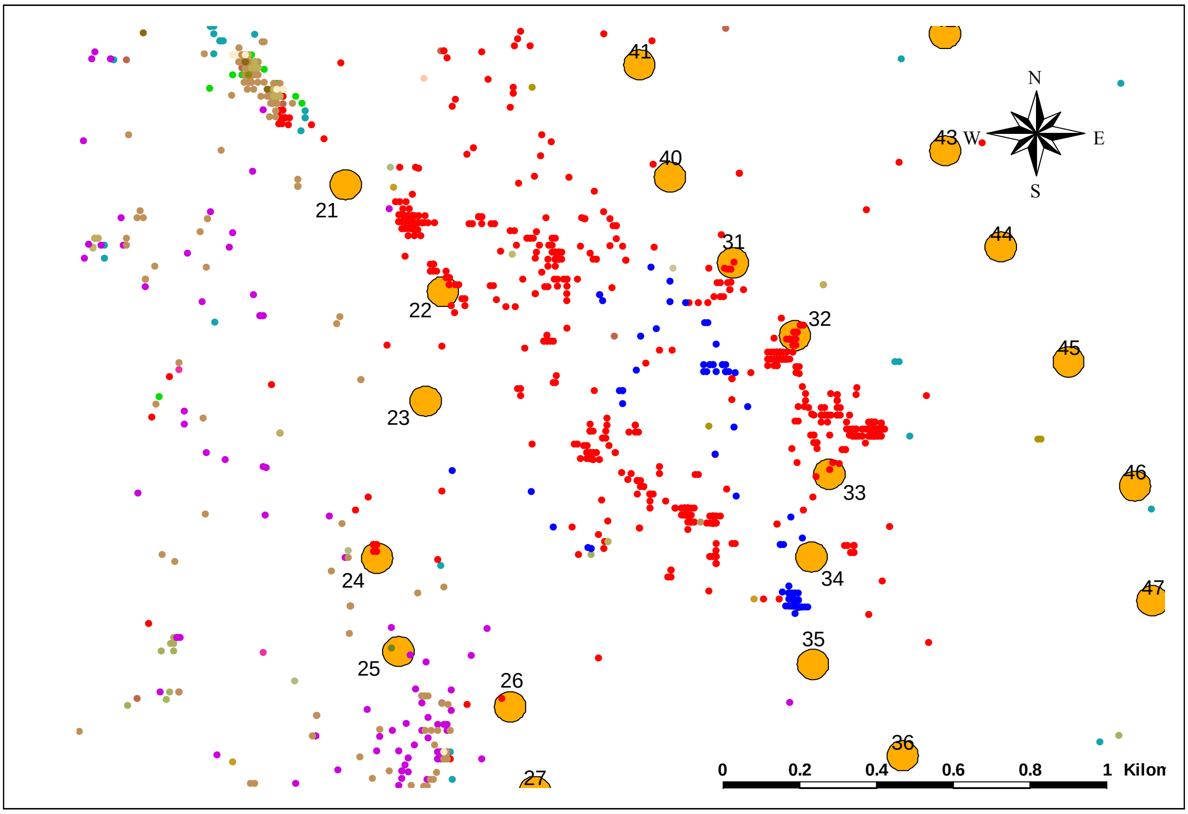


Figure 16. *GPS positions of juvenile white-tailed eagles in the northwestern corner of Smøla Wind-Power Plant. Same colour indicates same bird. The rotor-swept zone of the wind turbines are shown as yellow circles (41 meter radius), and denoted by their number in the park. The GPS accuracy is 10-15m.*

2.4.1.4 Estimating collision risk

An attempt to quantify the risk of juvenile tagged birds of being hit by rotors has been performed on the GPS data using a new statistical approach - "Brownian bridges". This statistical work has been done by Roel May, and was presented at an international conference in Prague in September 2009 (May & Nygård 2009).

Based on the GPS-data from the marked juvenile white-tailed eagles, we analyzed their susceptibility to collide with wind turbines. This analysis was based on Brownian-bridge interpolation simulations, and render insight into the risk rates (i.e. time spent within 'risky' areas relative to the total amount of time) in time and space. The analysis, due to be sent in a peer-review journal shortly, presents risk rates for the time spent within the wind-power plant, and within the vicinity of the wind turbines (i.e. within a circular buffer of ca. 40m). This analysis may thus render insight into periods and areas with heightened risk (Figure 17). This modelling approach can be utilized to direct mitigation measures in a wind-power plant when telemetry data is available; both in the pre- and post-construction phase.

Based on the same GPS-data, we have started a habitat-utilisation analysis also focusing on possible displacement effects in white-tailed eagles. The analysis is based on the estimation of utilisation distributions (UD) using the Brownian-bridge movement model BBMM (Horne et al. 2007); which gives an estimation of the probability of occurrence in an area (95% UD). These Brownian-bridge utilisation distributions were compared to habitat categories using resource utilization functions (RUF) (Marzluff et al. 2004), which are based on relative space use where the unit of study is the individual home range. This methodology is based on observed animal movements, while incorporating temporal autocorrelation between consecutive relocations and taking into account the measured location error, both inherent to GPS-based data.

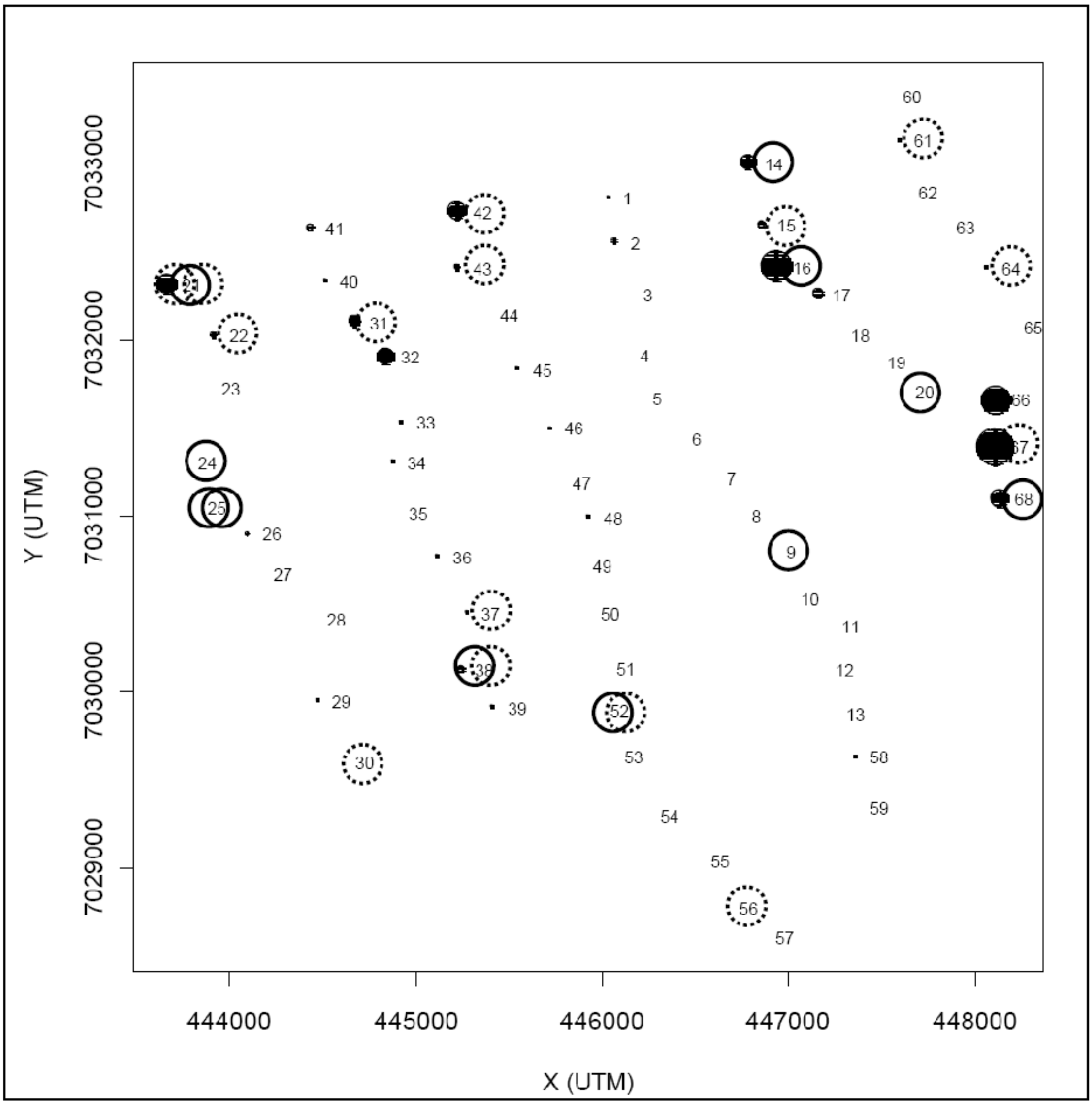


Figure 17. *Spatial representation of the relative (log-transformed) collision-risk rates per wind turbine within the Smøla Wind-Power Plant. The numbers depict the turbine numbers while the size of the black dots indicate the risk (no dot equals no risk, while larger dots indicate increased risk). Turbine numbers with solid and dotted circles indicate recorded juvenile and adult collision victims, respectively (each circle indicates one victim).*

2.4.1.5 The use of night roosts

As the satellite tags are giving positions day and night during the time of the year when they have enough battery charge, we were able to reveal the diurnal movements of the tagged birds. The results show that such movements are pronounced. The movements reveal some major night-roosts on Smøla, many of these used by several of the satellite-tagged birds. Passing in and out during morning and evening, they follow the same tracks on a day-to-day basis. Such knowledge should preferably be available before wind-power plants are planned in dense white-tailed eagle breeding areas. Figure 18 shows such use of night-roosts by individuals no. 83224,152455 and 158967. Intensively used night-roosts on Smøla for all birds are shown in Figure 19. In addition to these, there are other smaller, more temporarily used roosts. Note especially the two roosts in the north-western corner of the wind-power plant. Several eagles have been killed by turbines in this area.

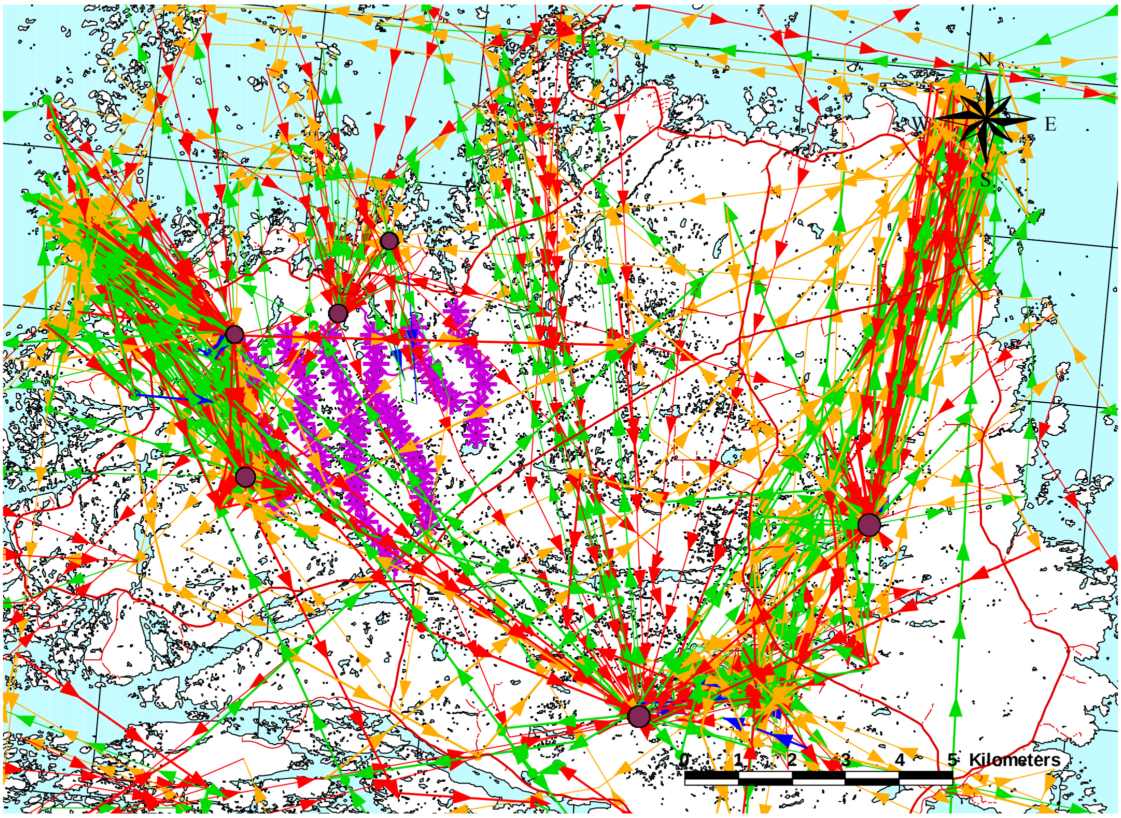


Figure 18 *The use of night-roosts of three juvenile sea-eagles satellite-tagged on Smøla. Green lines indicate morning movements (04:00-10:00), orange during the day (10:00-16:00), red during evening (16:00-22:0) and blue during the night (22:00-04:00). Arrows indicate direction of movement. Note apparent lack of movements at night. The wind-power plant is indicated by stars, night-roosts as brown circles.*

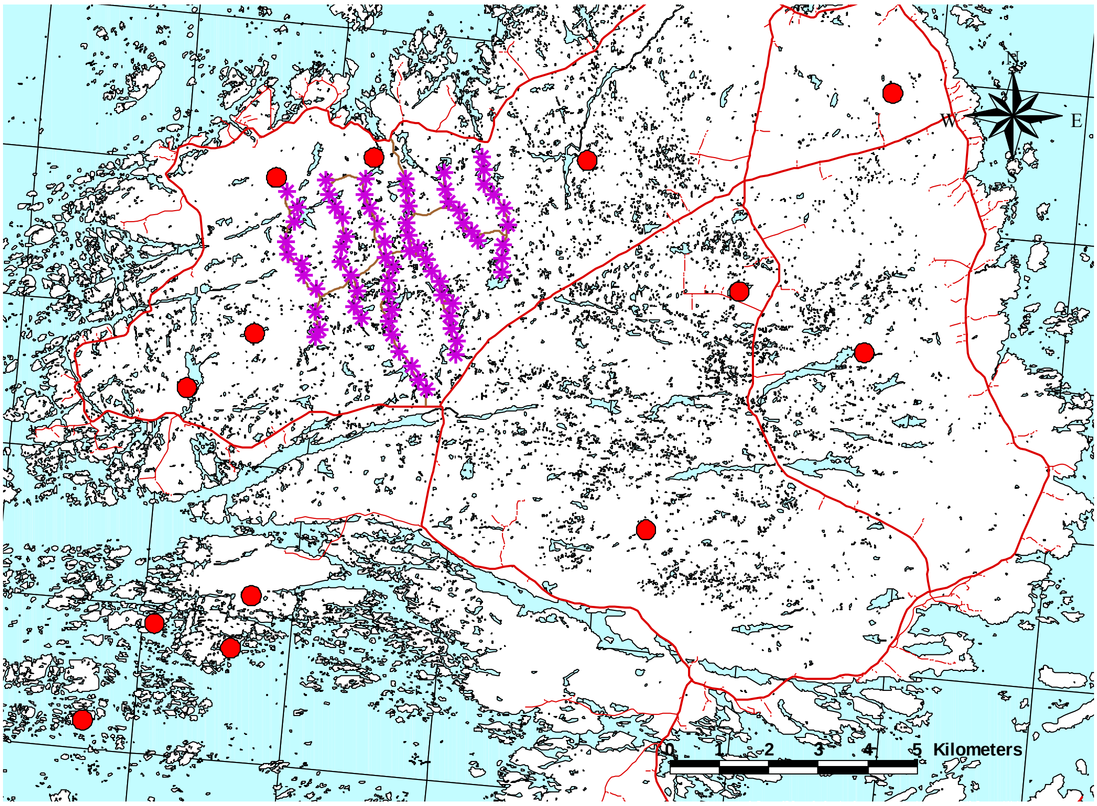


Figure 19. *Intensively used night-roosts (red circles) of satellite-tagged juvenile white-tailed eagles on Smøla. The turbines within the power plant is indicated by stars.*

2.4.1.6 Satellite tagging of adults

An attempt to capture and satellite-tag local breeding adult eagles was done in January/February 2009, by use of a remotely controlled cannon-net at a carcass bait monitored by a web-camera (Figure 20). The attempt failed, as the birds were quite reluctant to enter the carcass, but enough visits were recorded to encourage us for another attempt this coming winter. The logistics are better now, with the access to new housing facilities at the wind-power plant's technical and administrative centre.

Figure 20. *Three white-tailed eagles and two hooded crows at the carcass taken as snapshot from the web-camera. Two wind-turbine towers are visible in the background.*

The steadily increasing database on eagles' movements within and outside the wind-power plant area is enabling us to make steadily better risk assessments, and will hopefully serve as a tool for better planning of future wind-power plants on the coast of Norway.

2.4.1.7 Dissemination of results

Results and analyses from the satellite-tagging have been presented at three international conferences in 2009; in Elliot City, Maryland, USA (Nygård et al. 2009b), at the 2nd European Congress of Conservation Biology in Prague, Chech Republic, September 1-5, 2009 (May & Nygård 2009), and at the Raptor Research Foundation annual meeting in Pitlochry, Scotland, September 2009 (Nygård et al. 2009a).

2.4.2 Genetic analyses

Subproject responsibility: Arne Follestad, Øystein Flagstad

Objective: The main goal is to estimate adult mortality among breeders in, or close to, the Smøla Wind-Power Plant based on DNA-analyses of WTA-chick plucked feathers and moulted feathers from adult birds. Mortality figures will be compared to the mortality among breeders at increasing distance from the wind-power plant as well as mortality in a control population not influenced by wind-power development. The control population counts slightly more than 20 breeding pairs.

Previous analysis has shown that females are most easily sampled from this approach (more frequent moulting). However, males also moult regularly, and analysis of a sufficient number of feathers from each nest should give good data on both males and females. As such, the goal is to build a time-series database covering at least 80% of the breeding population on Smøla. The time-series data from the wind-power plant and the control area will give a unique possibility to address adult mortality in white-tailed eagles, and model the potential negative effect on population growth rate of the wind-power plant. This will contribute with valuable data for evaluating the overall general effects of wind-power plants, which in turn will provide an important dimension in forming sustainable future directions for wind-power development.

Figure 21 *The GeneMole instrument, which has now been implemented in the project to streamline the production of DNA-data from feathers and tissue of dead eagles.*

2.4.2.1 Activities and findings

The feather-collecting activity have continued from active nests and chicks also in 2009, as well as from eagles killed in collisions with wind turbines. DNA-analyses from bones from six electrocuted on Smøla (cf. 1.6) will also be included. Sampling of feathers from a total of 69 white-tailed eagle territories in 2006-2009 can be summarized as follows:

Feathers sampled all four years	15 territories
Feathers sampled three years	13 territories
Feathers sampled in two years	19 territories
Feathers sampled in one year	22 territories

For increased efficiency in the laboratory and to streamline the production of DNA-data, we have implemented the use of an extraction robot. Two GeneMole instruments (Mole Genetics AS, Lysaker, Norway) are available in the laboratory (Figure 21) and we have now started to use the instruments in the handling of feather material from 2008 and 2009. In comparison to the previous manual extraction protocol, we have experienced an increased success-rate for DNA-profiling of individual samples, which is now higher than 90%. Moreover, the implementation of the automated extraction protocol allows a highly reduced handling time for each sample, which in turn contributes to efficient production of reliable DNA-profiles.

The DNA-profiling of moulted feathers and chicks at the nests has allowed generation of a database on individuals from the breeding territories on Smøla. Prior to the analysis conducted in 2009, the full couple (male + female) in 19 territories have been identified, which is approximately 35% of the territories sampled in 2006 and 2007. The rest of the territories are provisionally represented by one bird only, most often the female. Limited resources have hampered an even higher representation of full couples, but given sufficient funding, it seems realistic to fulfil the goal to produce a database comprising at least 80% of the breeding population.

The data from 2008 and 2009 will soon be included in the database. Thereafter, additional feathers will be analyzed in a number of territories to increase the proportion of full couples (male + female) that are represented in each territory. The data-collecting activities will continue in 2010 together with analyses of the reference material from the control population. Material from 16 territories collected in 2009 is now available for analysis.

2.4.3 WTE breeding success

Subproject responsibility: Espen Lie Dahl

Objectives: To monitor possible changes in the WTE-breeding population abundance on Smøla caused by the development of the wind-power plant, and study whether the plant has any short- or long-term effect on the eagles' reproduction and breeding success.

2.4.3.1 Activities and findings

All WTE nest sites on Smøla were surveyed during the summer. Territorial activity, identified by either moulted adult feathers, chicks in the nest or fresh nest material, was confirmed in 61 different territories on the main island and in the surrounding archipelago (Figure 22). In these territories 27 chicks from 21 different clutches were recorded. This is the second highest number of chicks recorded ever on Smøla, and gives a reproductive output of 0.44 chicks/confirmed occupied territory (o.t.) (Figure 23). Although being slightly better than the results from 2008 (0.36 chicks/o.t.), 2009 was an average production-year when corrected for number of active pairs. Within the area of the wind-power plant there was one successful breeding, producing one chick. In addition, one more pair laid eggs which hatched, but the pair discontinued its breeding attempt during the early chick period for unknown reasons. In the border zone surrounding the wind-power plant (0-2km from the turbines) 3 pairs bred successfully, producing 4 chicks. One of these chicks was found killed beneath a turbine in October.

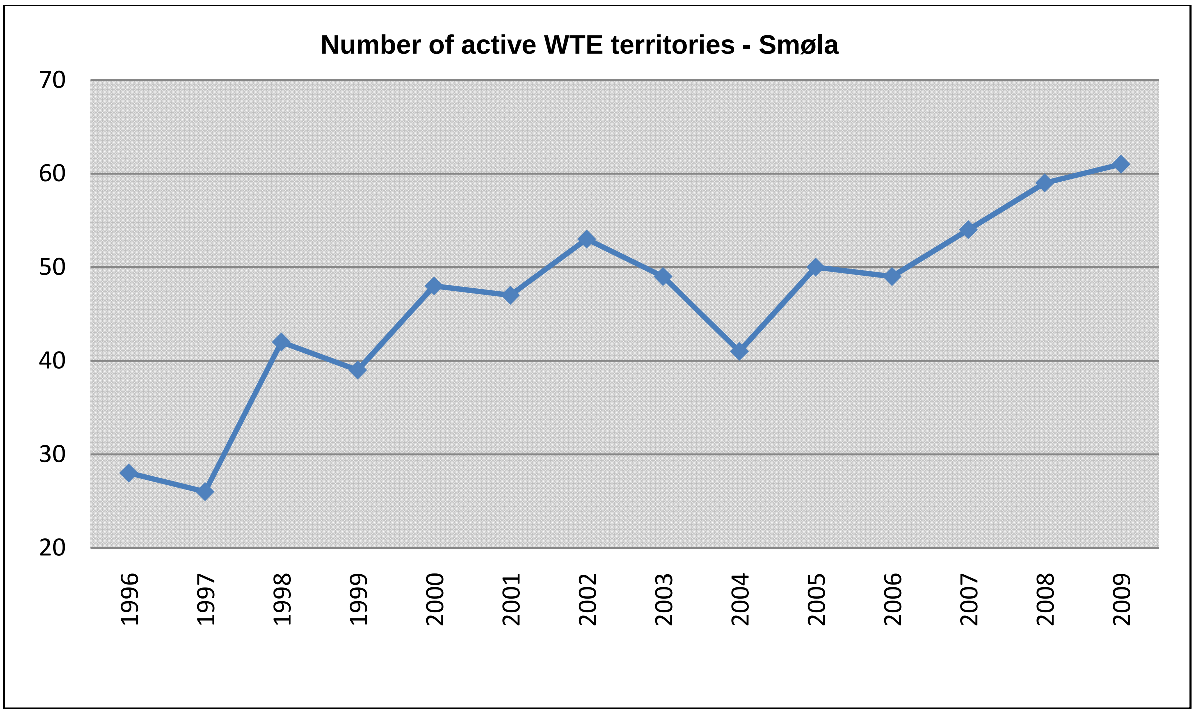


Figure 22. *Number of WTE territories with recorded territorial activity on Smøla during the period 1996-2009*.

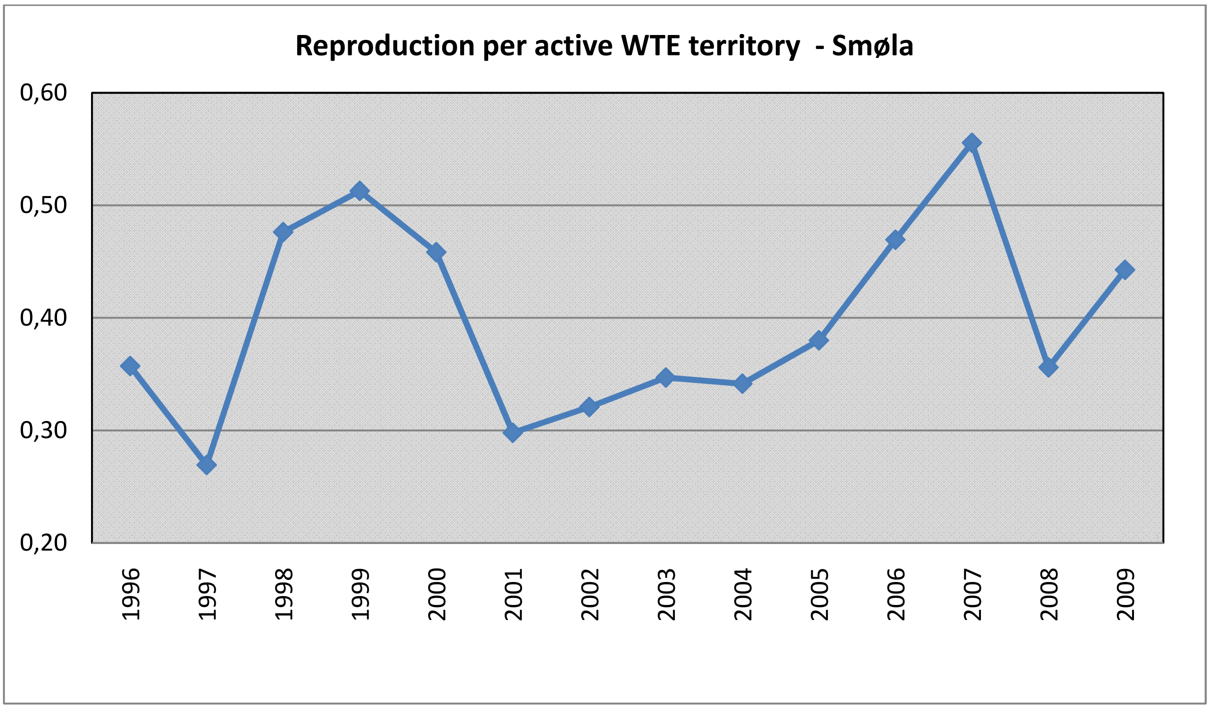


Figure 23. *Reproduction per confirmed active WTE territory on Smøla during the period 1996-2009.*

Interestingly 8 new territories were discovered on Smøla in 2009, probably as a result of intensive search. In addition one territory that has been left empty for several years became occupied again. All of these, except one, were in the archipelago surrounding the main island, while the last one was a pair producing one chick approximately 2km southwest of the wind-power plant. DNA-analyses of moulted adult feathers collected at the nest sites will probably reveal whether these birds establishing new territories are birds entering the population, or if it is birds displaced from their original territories and establishing new territories.

The real population size on Smøla is very likely to be higher than the number of territories with confirmed activity each year. This is due to the fact that WTE pairs not breeding every year, and in the intermittent years the behaviour of pairs not breeding can be very inconspicuous. The actual population size will be revealed by genetic analyses, but is likely to be in the range of 65-70 adult pairs. In addition to the territorial pairs there is an unknown number of “floaters”. These are adult, or near adult birds, not paired up and established in their own territories. This part of the population buffers the breeding population, with “floaters” filling in vacant territories. Through intensive population monitoring, we will hopefully be able to quantify also this part of the WTE population. This will be an important contribution to understand the dynamics in the WTE population on Smøla.

There has been a trend during the last breeding seasons of poor breeding success inside the wind-power plant area, while the border zone surrounding the plant has experienced better reproductive success. We analysed the pre- and post-construction density of occupied territories on Smøla using Harmonic Mean densities in ArcView GIS 3.3, comparing the active territory density from the breeding seasons 2000 and 2001 with the active territory density during the breeding seasons in 2008 and 2009. The overall results (Figure 24 and 25) indicate a slight increase in territory density in the archipelago, while high-density areas on the main island are more or less confined to the same areas in the two periods. A closer look at the wind-power plant area (Figure 26 and 27) reveal that this area had a high pre-construction territory density, where the high density area covered more or less all parts of the area now occupied by the plant (Figure 26). The territory density during the breeding seasons 2008 and 2009 has shifted southwest compared to the pre-construction period (Figure 27), going from high density in the whole plant area prior to construction to low density in the centre and increased density in the south-western outskirts after construction of the power plant. The explanation to this shift in high density areas is probably due to a mix of factors, involving increased disturbance, increased mortality and loss of habitat. It also explains the low number of chicks produced inside the plant area during the last breeding seasons. Because WTEs have strong territory fidelity these processes are not detected without long-term population monitoring. A continuation of the intensive monitoring will reveal whether this is a trend that will continue or whether the abandoned territories within the power plant will become occupied again at a later stage.

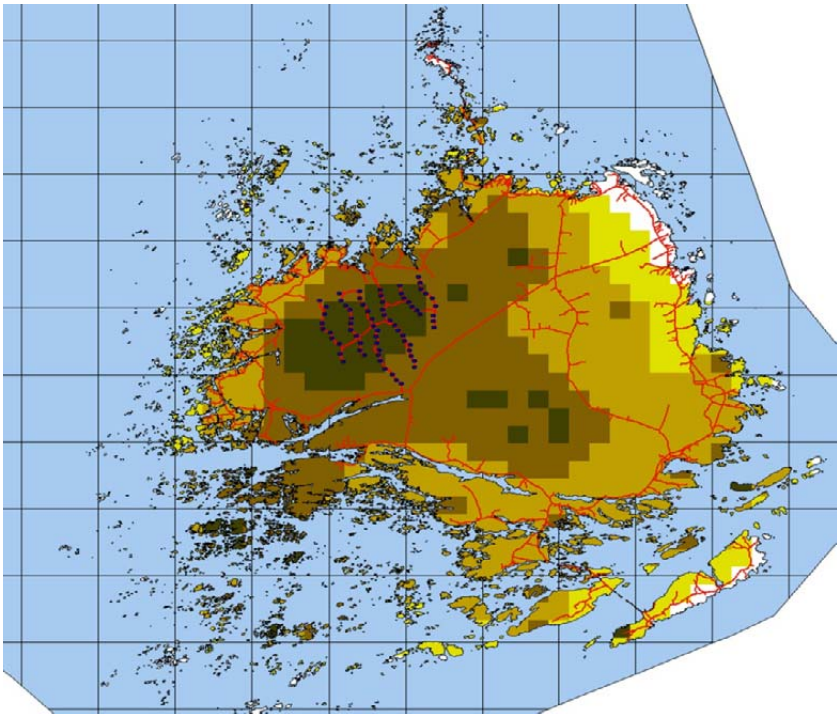


Figure 24. *Densities of occupied WTE territories on Smøla in 2000 and 2001 calculated using Harmonic Mean in ArcView GIS 3.3. Darker colour indicates higher territory density.*

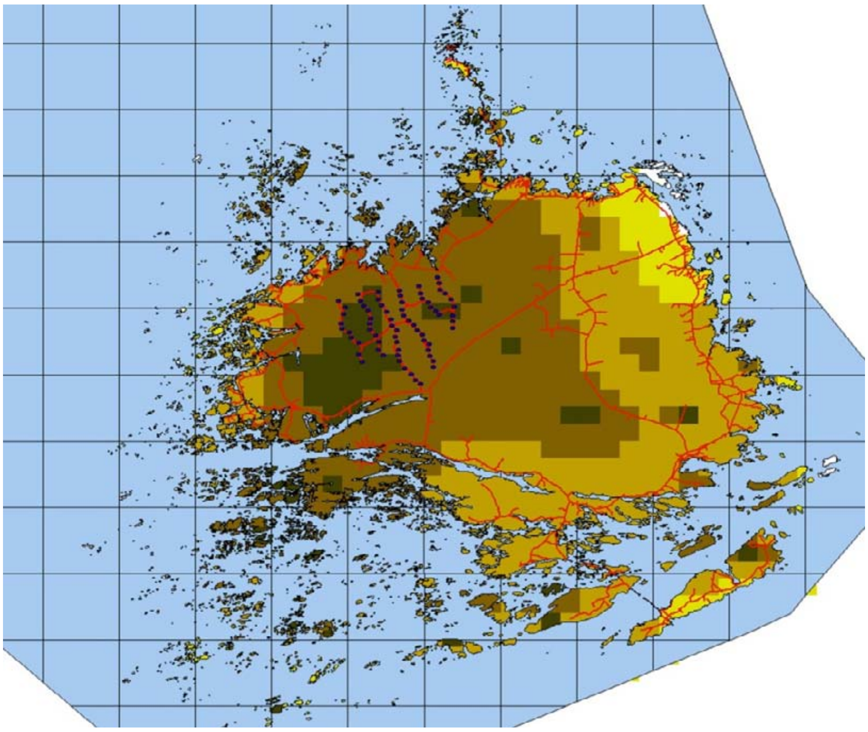


Figure 25. *Densities of occupied WTE territories on Smøla in 2008 and 2009 calculated using Harmonic Mean in ArcView GIS 3.3. Darker colour indicates higher territory density.*

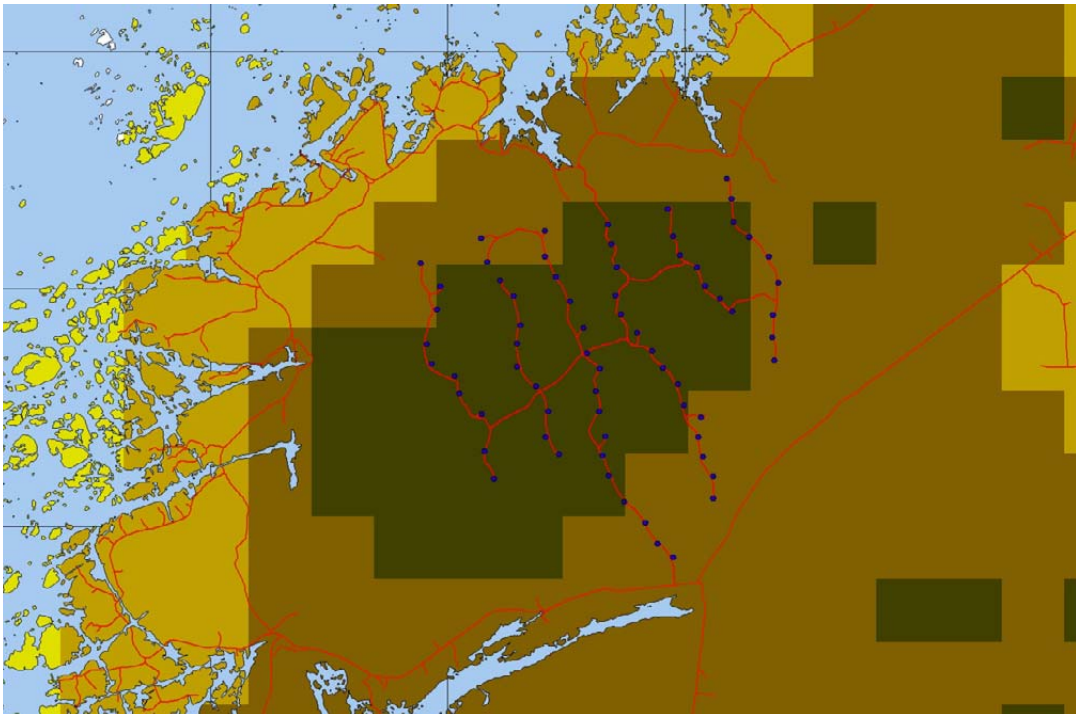


Figure 26. *Densities of occupied WTE territories inside and close to the Smøla Wind-Power Plant in 2000 and 2001 calculated using Harmonic Mean in ArcView GIS 3.3. Darker colour indicates higher territory density.*

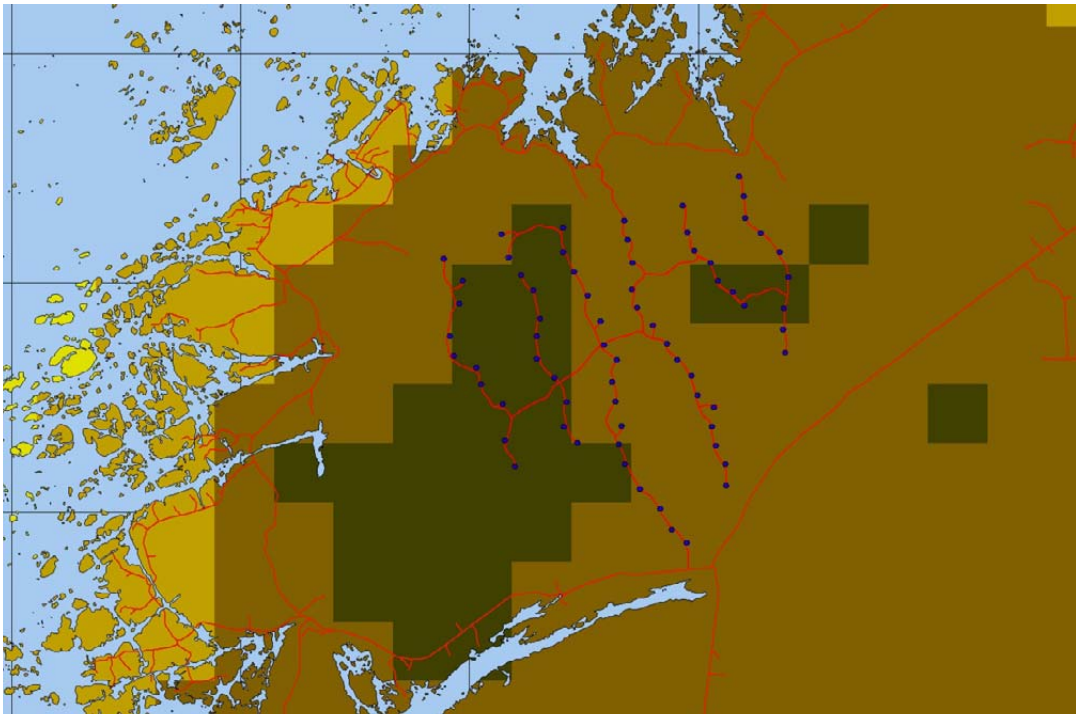


Figure 27. *Densities of occupied WTE territories inside and close to the Smøla Wind-Power Plant in 2008 and 2009 calculated using Harmonic Mean in ArcView GIS 3.3. Darker colour indicates higher territory density.*

2.4.4 WTE behaviour inside and outside the wind-power plant area

Subproject responsibility: Pernille Lund Hoel, Kjetil Bevanger, Hans Chr. Pedersen, Eivin Røskaft, Bård Stokke

Objectives: Observation of WTE behaviour inside the wind-power plant area and in an adjacent control area, to collect data on possible behavioural differences as a response to the wind-power plant.

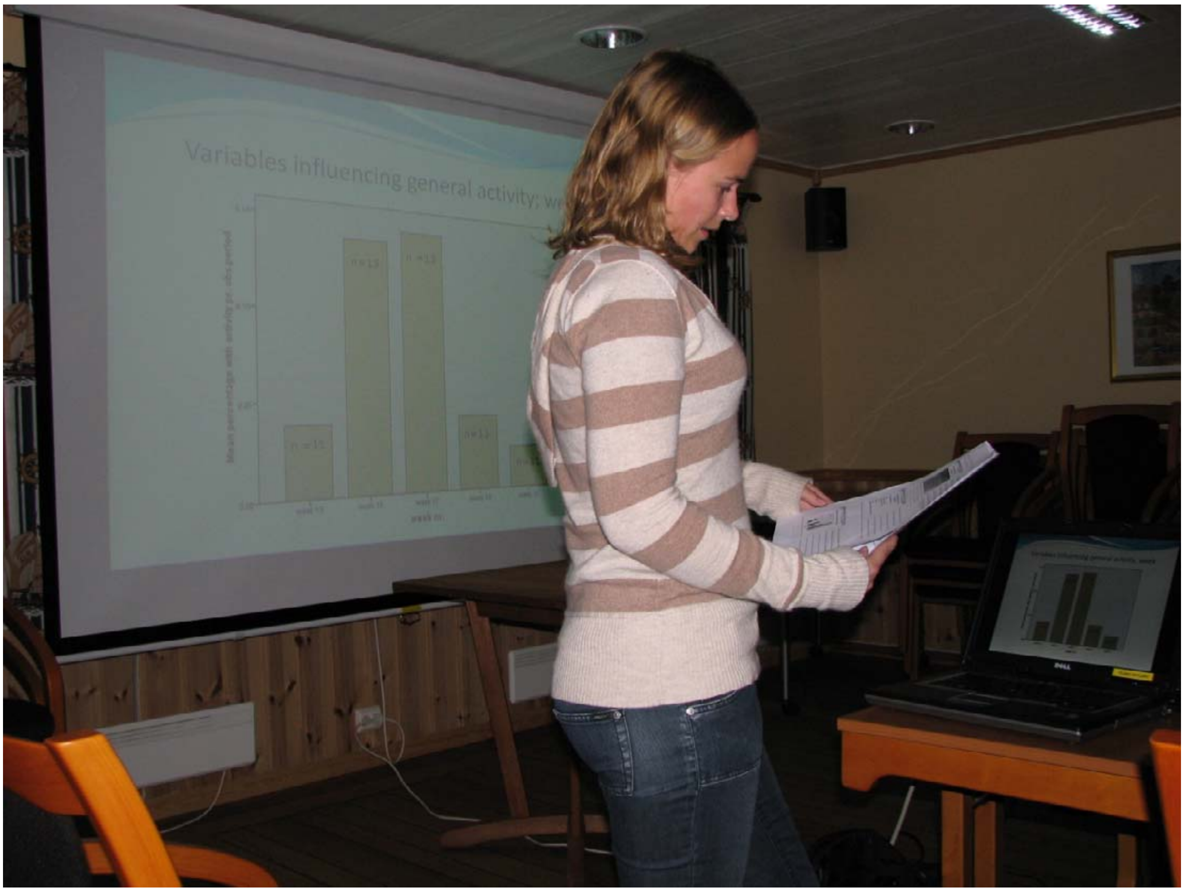


Photo 10. *Pernille Lund Hoel elaborates on her findings at the Annual Meeting in March.* Photo: Kjetil Bevanger.

2.4.4.1 Activities and findings

In order to investigate behavioural differences related to the distance from the turbines, data on flight activity (moving flight, social behaviour and soaring) and flight height (below, in and above the rotor zone) were collected at 12 vantage points, 6 from inside the wind-power plant area and 6 from control areas close to the power-plant area. In order to investigate possible differences inside the wind-power plant versus the control area, observations from the 12 vantage points have been separated into two groups (6 vantage points in each) in some of the analysis and named control area (CA) and wind-power plant area (WPA).

First, possible explanatory variables that could account for variation in general activity were investigated. Second, variables that could account for variation in flight activity and flight height were investigated, and third variables that could explain differences between the flight activities and flight heights were investigated.

Any variation in the two response variables (flight activity and flight height) could possibly be explained by several different explanatory variables. In order to investigate which variables that influence on variation in the response variables, data were collected on distance to nearest turbine, distance to nearest active nest, number of individuals observed together, date, time of day, weather (precipitation, temperature and wind speed), and age of individuals. Data collected from 144 observation hours, during mid-March to the end of May 2008, were analyzed using ANOVA, Chi-square tests and multinomial logistic regression.

The only explanatory variables that showed a statistically significant effect on the general activity were week number and distance to nearest active nest. The results showed a statistically significant difference in activity among the weeks. The general activity peaked in April (week 15 and 17) which is the first part of the breeding period for the WTE (Figure 28). Moreover, more activity was observed at distance 0-500 m than further away from the nearest active nest. There was more activity at 0-500 m than further away from the nest, which probably could be due to defending territories and delivering food to the nest (Dementavicius & Treinys 2009). Neither distance to nearest turbine, nor the locations seem to have any effect on the general activity.

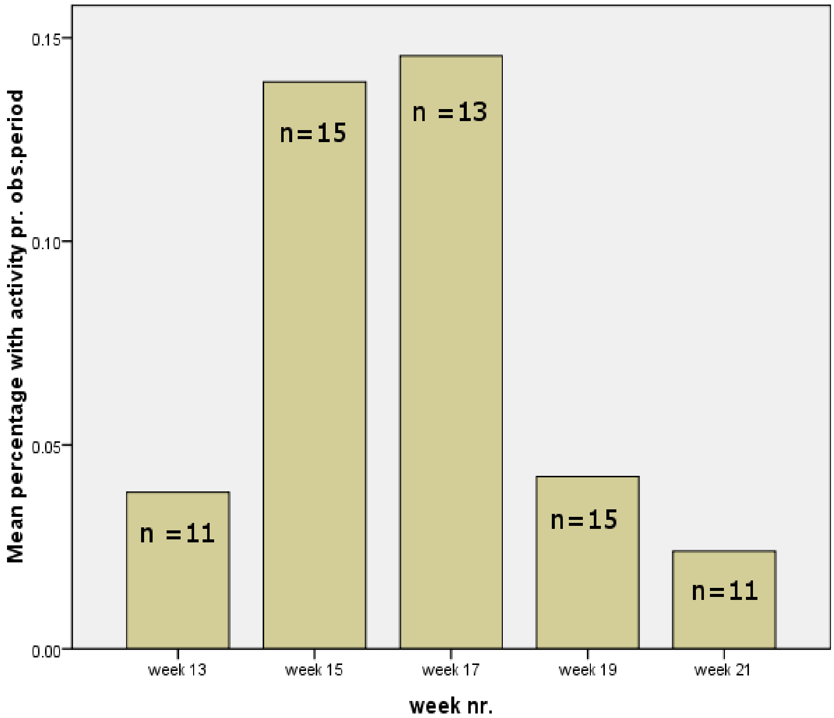


Figure 28. *Observed flight activity (%) of WTE of total observation time pr. observation week. N=number of two-hour observation periods.*

The results showed, furthermore, a statistically significant difference in age distribution between the two locations, with a higher percentage of adults in the CA and a higher percentage of subadults in the WPA (Figure 29). There was also a statistically significant difference between the age categories in the different observation weeks with more adults than subadults represented throughout the whole study period.

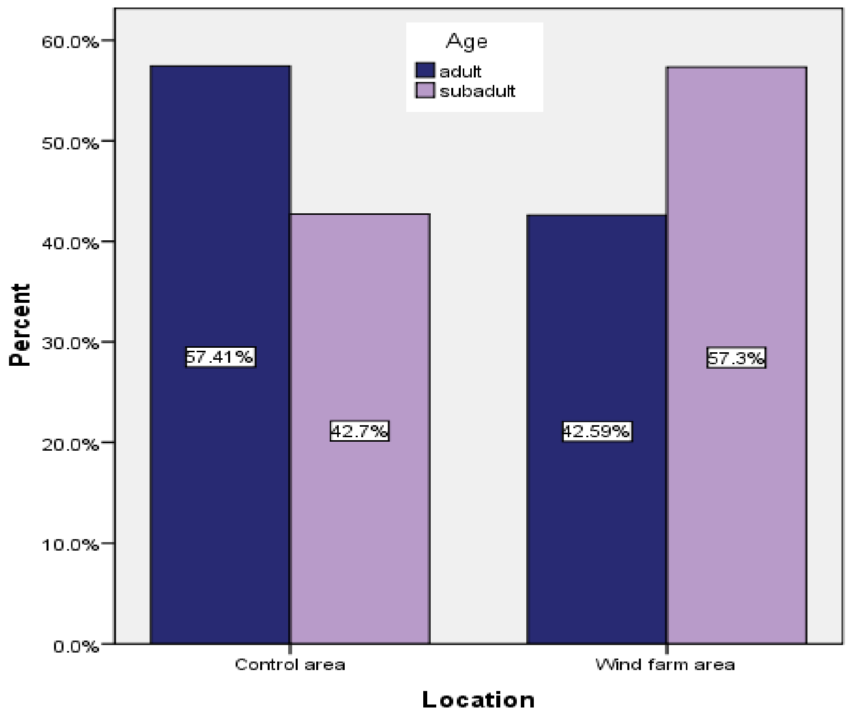


Figure 29. *Age distribution (%) of WTE in the control area and the wind-power plant area ($N_{CAadult}$=182, $N_{CASubadult}$=79, $N_{WPAadult}$=135, $N_{WPAsubadult}$=106).*

Regarding flight activity, the results from the multinomial regression analyses showed a statistically significant difference between moving flight and soaring in number of individuals observed together, with more individuals observed together in moving flight than in soaring (Figure 30). This could possibly be caused by pairs of individuals performing moving flight when moving back and forth between territories and feeding areas (Dementavicius & Treinys 2009).

Furthermore, there was a statistically significant difference between social behaviour and the two other activity categories in number of individuals observed together, with more individuals observed together in social behaviour than in moving flight and soaring. There was also a significant difference between social behaviour and the other two activities related to age, with more adults than subadults in social behaviour than in moving flight and soaring. Since adults are reproductively active in contrast to subadults, and therefore more likely to participate in social behaviour in order to increase their fitness, this result is as expected.

Soaring was statistically significant different from the two other activity categories in relation to flight height, with soaring only occurring in – and above the rotor height, while moving flight and social behaviour occurred in all three flight-height categories. One reason for this is that the WTE can climb in altitude during sustained soaring and in this way gain high altitudes.

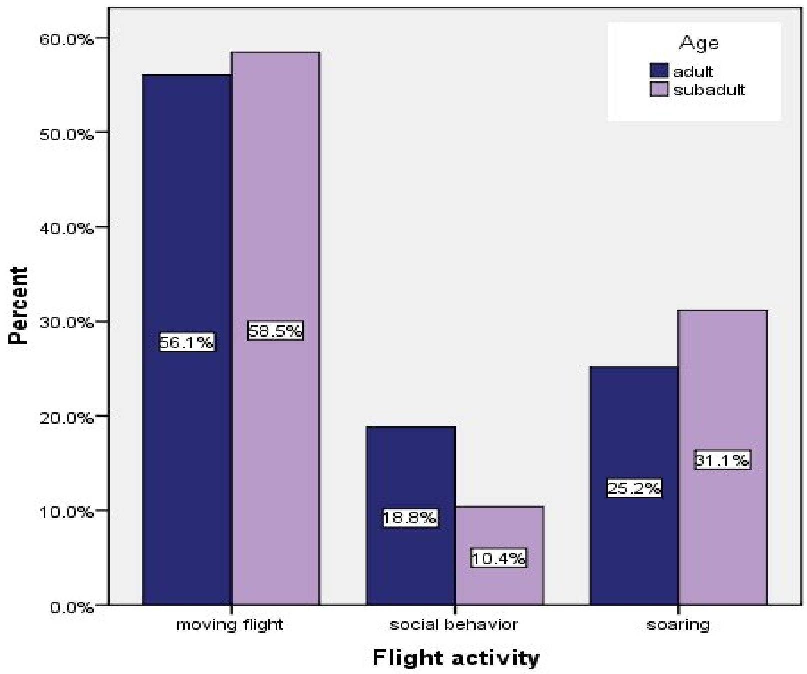


Figure 30. *Observed age distribution (%) of WTE in the different flight activity categories.*

Furthermore, a statistically significant difference in age distribution between the two locations appeared, with a higher percentage of adults in the CA and a higher percentage of subadults in the WPA. This finding could indicate that the adults are either behavioural displaced away from the WPA, or that there are a higher percentage of adults than subadults killed inside the WPA. One possible reason for this difference could be connected to social behaviour. A much higher percentage of adults than subadults are involved with this type of behaviour, and this can possible impose a greater risk due to decreased awareness of the surroundings, or/and the fact that there are more activity in the air during the period were social behaviour are most important for pair-bounding, as also the analyses of the effect of week number on the general activity suggest.

Because of low sample sizes due to low breeding densities, raptors are among the most difficult group of birds to demonstrate effects of disturbance, thus more long-term studies are needed. In order to test the assumption about social behaviour imposing greater risk to collision than the other flight activities, it is therefore necessary to conduct more long-term studies. More studies will also give larger sample sizes, which can give the opportunity to distinguish between more types of flight behaviour (e.g. more types of social behaviour).

Other studies (Henderson et al. 1996) indicate that moving flight could impose a greater risk than the flight activities because adults are flying more frequently under or between man-made structures in order to reduce their journey time when rising young. The present study show that moving flight is the activity that is most observed both in the WPA and the CA, and in both age categories. One alternative explanation for the high amount of adults found killed could therefore be that moving flight in relation to parental care could impose a higher risk for the adults than the subadults.

These results indicate that the WTE on Smøla does not have any behavioural responses to the wind-power plant construction. It may, however, contribute to explain why the WTE is vulnerable to collisions with the turbines and the number of killed individuals recorded within the power-plant area. The results may also contribute to explain the high percentage of adults found killed in the

WPA. The WTE has a peak activity during the start of the breeding period, which can be fatal to both adult individuals and thus also the nestlings. This should be carefully considered when looking at the possible long-term effects of the wind-power plant on the WTE population on Smøla.

2.4.5 WTE autopsy

Subproject responsibility: Finn Berntsen

Objectives: Identify the cause of death based on inner/outer injuries on the dead WTE recorded in connection to the wind turbines, and identify characteristics of lethal wind-turbine imposed injuries.

2.4.5.1 Activities and findings

In 2009 30 dead WTEs recorded in connection to the wind-power plants on Smøla and Hitra have been examined. The eagle carcasses varied considerably with respect to what a post-mortem examination could reveal. Some birds were newly dead, while others were more or less free of soft tissue and quite desiccated. The condition of most carcasses did not allow for a thorough classic autopsy. Nevertheless, all eagles were x-rayed. Three willow ptarmigan and one merlin recorded on Smøla are also autopsied. The precise findings and assessment will be presented later in a scientific paper. A majority of the eagles had multiple severe fractures to their skeletons (Figure 31).

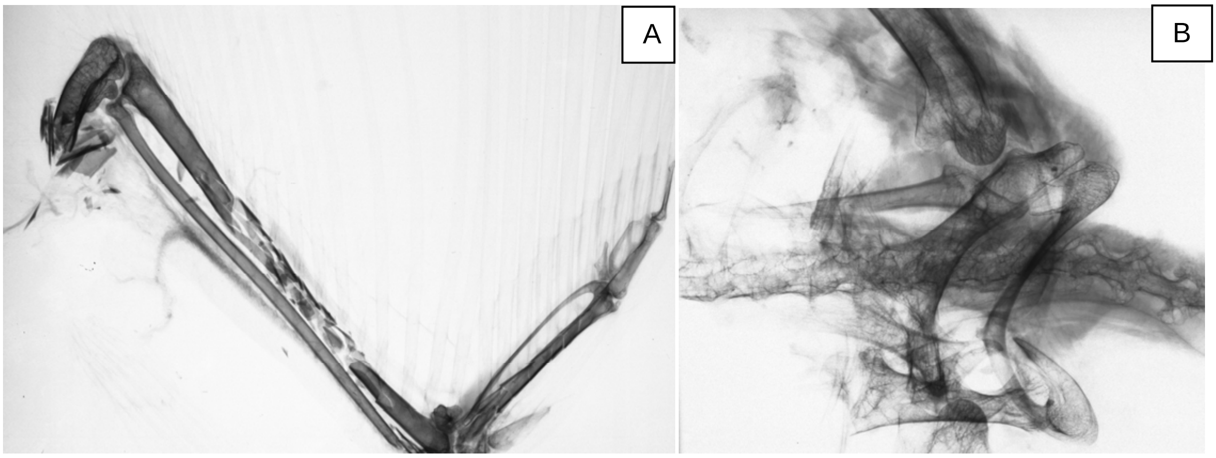


Figure 31. *Example of fractures on WTE cut in two pieces by the rotor blades on a wind turbine. The cutting line was from front of sternum towards the kidney region. There was no damage to the left wing. The right wing attached to the body had multiple fractures in both humerus and radius/ulna (A). Picture of disintegrated knuckles on the same bird (B). Considerable external force applied to the body is the only explanation to the comprehensive damage*.

2.5 Bird radar studies

Subproject responsibility: Roel May, Yngve Steinheim

Objectives: Development of radar as a tool for learning more about the effects of single wind turbines and wind-power plants on birds.

2.5.1 Activities and findings

The main focus in 2009 have been development of GIS-tools to learn more about the radar range and scanning accuracy (see also 2.8.), development of database routines (see also 2.7.)

to optimize radar data (including false alarms filtering and categorization of bird tracks using data-mining techniques), and experimental tests of the radar performance with respect to accuracy in detecting and following birds using model aircrafts and ground-truthing (identify bird species spotted by the radar by field observations). Methodological challenges of the radar system are to which extent the tracking-algorithm is able to record bird flights, verification of recorded radar tracks to species and characterisation of species-specific track-characteristics to enable extrapolation to the entire database.

2.5.1.1 Ground-truthing and track database

Since the start of the project 1,617 bird track segments have been ground-truthed (Figure 31). A ground-truth protocol has been established to enable a representative collection of data. Using a rugged laptop, which is remotely connected to the radar monitors through the GSM-network, groundtruth-data can be collected at any given vantage point within the range of the radar. This ensures that data is collected at different turbines, in different environments and at different distances from the radar. Based on this database, the radar-detection capability and species-specific parameters (e.g. size, shape, reflectability, speed, movement pattern) can be identified, which characterize the species within the radar system. This "radar-characterisation" of different bird species enables extrapolation to radar targets/tracks with a similar signature.

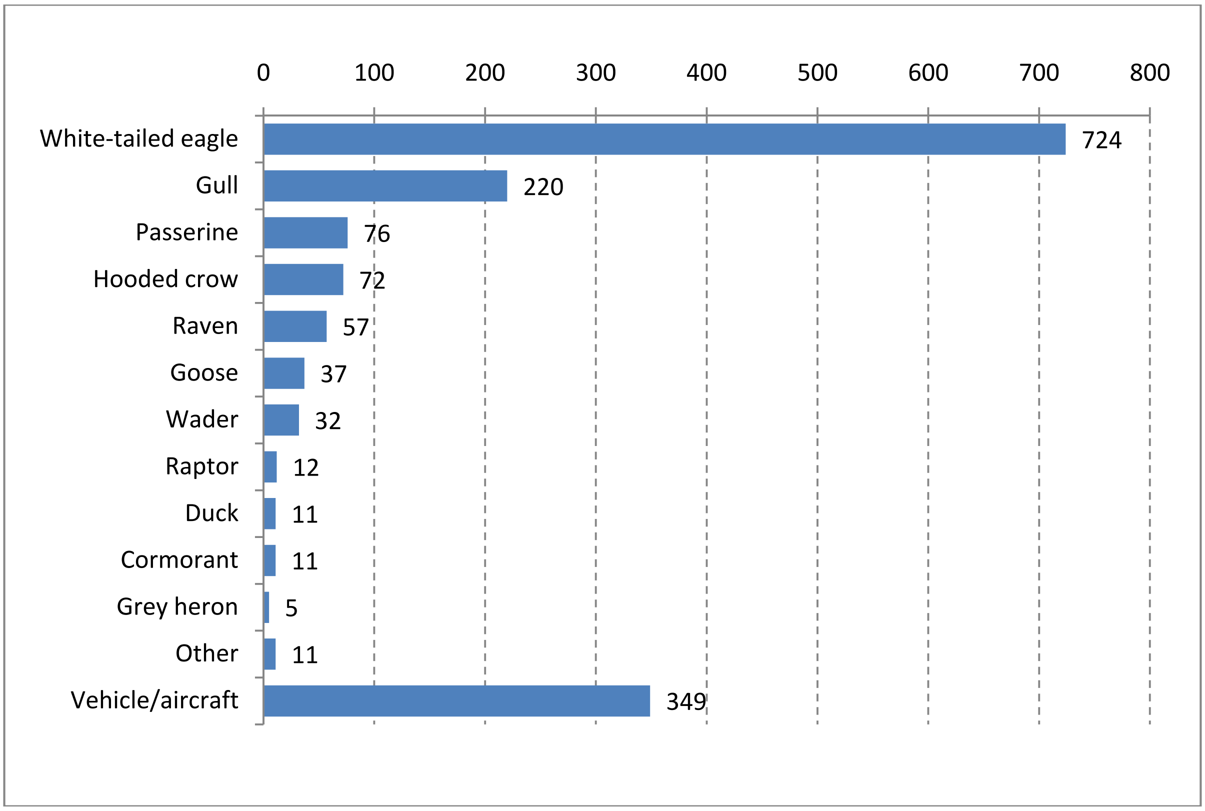


Figure 32. *Number of ground-truthed radar tracks for each given bird species (group) during the period 02.04.2008 – 11.10.2009 on the horizontal S-band radar. The many vehicles/aircraft groundtruthed reflect the testing activity with the model airplane.*

The development of database routines to optimize radar data has resulted in a framework which employs data-mining techniques (in order to filter out false alarms and classify bird tracks to species (group)). The framework builds on a random selection of tracks from the entire radar database. For each track a summary is calculated giving the average and variation in speed, acceleration, target size, reflectivity and tortuousity (i.e. a measure for the 'twistedness' of the track). Microsoft SQL Server Data Mining Clustering technique is used to identify the clusters found within the multidimensional space of this track-data set (Figure 33). Thereafter the ground-truth data is used to verify in which clusters these tracks of known birds (and species) fall. Other (unknown) tracks within the same cluster thereby should be to birds as well, however, the methodology still has to be optimized. This can be done by inclusion of more parameters; e.g. track- and target parameters (e.g. giving, biological relevant, information on the birds shape), weather data (as this will often result in an increase in false alarms), and clutter areas (i.e. areas where false alarms may be expected due to turbine interference; see also 2.8.). Also further optimization of the Clustering technique itself will improve the outcome: e.g. number of allowed clusters, model tuning, and testing other algorithms like Naïve Bayes and Neural Networks.

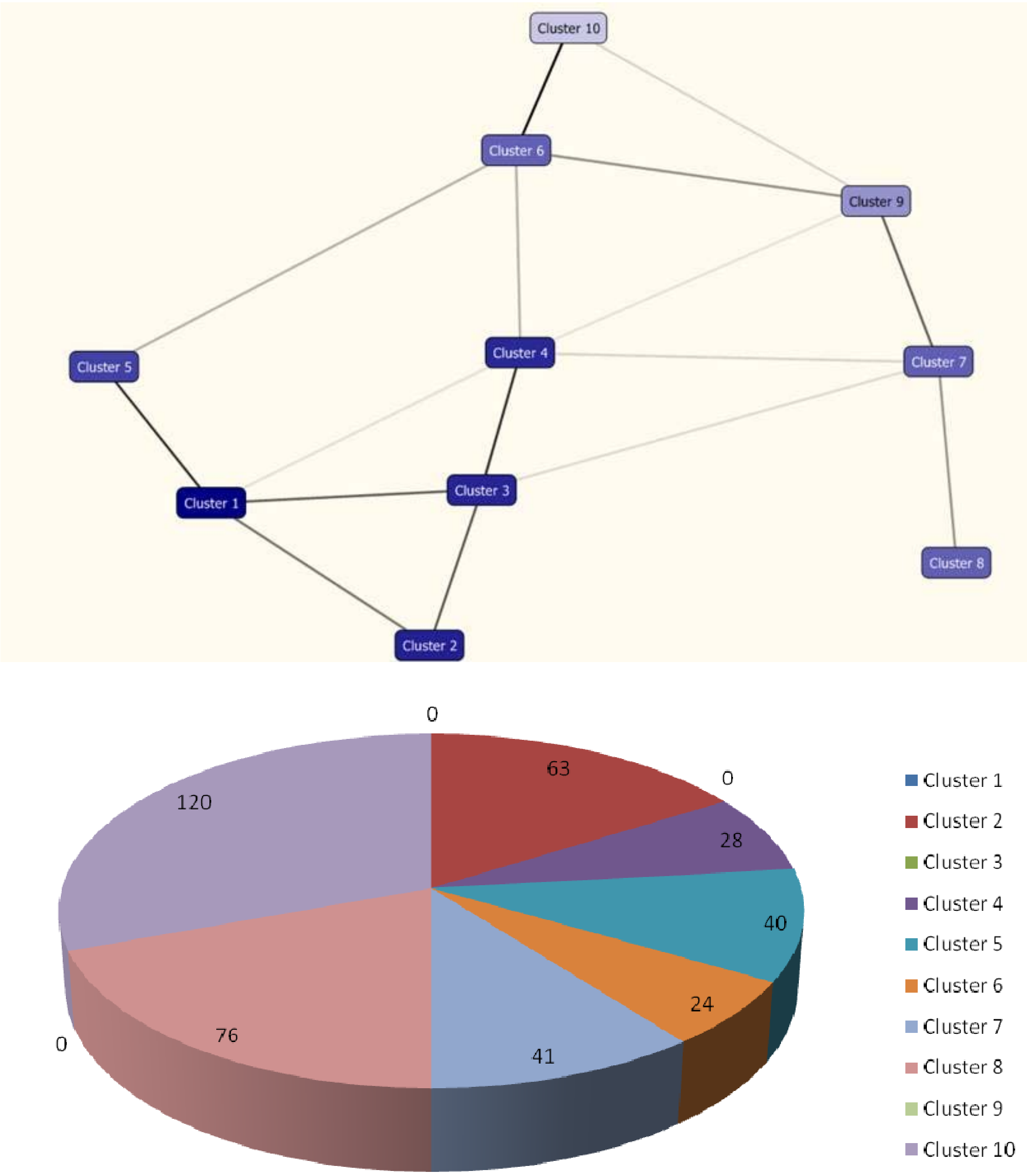


Figure 33. *Preliminary results from the Microsoft SQL Server Data Mining Clustering technique based on a test database. The pie chart gives the distribution of the ground-truth tracks over the different identified clusters. 50% of all ground-truth tracks fall within cluster 8 and 10, where cluster 10 has the highest cluster probability of on average 0.61 ± 0.03 SE.*

The aim is to finalize the methodological aspects of the radar operation and database optimization by the end of this year and the beginning of 2010. Thereafter analyses of the radar data will be the main focus. The analyses will likely focus on the following topics:

- Avoidance of wind turbines in birds (response distances, avoidance probabilities)
- Bird activity and weather correlates (together with Mark Desholm, NERI)
- Building a spatio-temporal dynamic collision risk model

2.5.1.2 Radar performance

Investigation into radar performance, and verification of the basic radar performance parameters such as resolution, accuracy and detection range, is necessary in order to develop a clear understanding of the avian radar system capabilities and limitations. This knowledge is considered crucial background in off-line analysis of recorded bird tracks. The main approach taken to radar-performance testing has been to use a controlled test target in live flight tests in the actual operational environment inside the wind-power plant area.

The first trials were made using a small conducting sphere as the test target. To move the test target around within the radar coverage, the sphere was towed behind a remotely controlled model aircraft. The advantage of using a sphere as the test target is that its size, i.e. Radar Cross Section (RCS), is accurately known for any given radar wavelength and related to its radius with a simple formula. This would make it possible to test the radar with different size-test targets simply by using different size spheres. Unfortunately the actual radar resolution, given by the extraction algorithms in the radar processor, was not narrow enough to allow for proper resolution with the towing aircraft at practical line lengths. In addition; towing a sphere behind a model aircraft poses a real challenge to the remote-controlling pilot on the ground, and places severe restrictions on the freedom to manoeuvre and thus limiting the flight patterns possible to perform. Therefore this method had to be abandoned. Instead the model aircraft itself has been used as the test target.

To be able to conduct long-range radar tests, NINA has rigged a model aircraft with video camera and video transmitter (Figure 34-36). This enables flying beyond visual sight range. In august 2009 ranges in excess of 2km from the pilot position where obtained. The aircraft is controlled on the 35MHz band, and the onboard video transmitter is transmitting on the 2,4GHz band. The aircraft is controlled using video goggles, also known as First Person View (FPV) flying.

Figure 34. *Pilots view with video goggles.*

Figure 35. *Controlling model aircraft with video goggles.* Photo: Yngve Steinheim.

Figure 36. *Model aircraft with video camera and transmitter.* Photo: Pål Kvaløy.

This technique has provided the freedom to design and perform virtually any test-flight pattern within the wind-power plant area. In addition, an on-board GPS logger accurately records the aircraft position during the flight. The recorded GPS data is then compared to the target position reported by the radar for the same flight, and serves as an aid to do both accuracy and detection analysis. Figure 37 illustrates an example of recorded radar tracks together with the GPS aircraft position data.

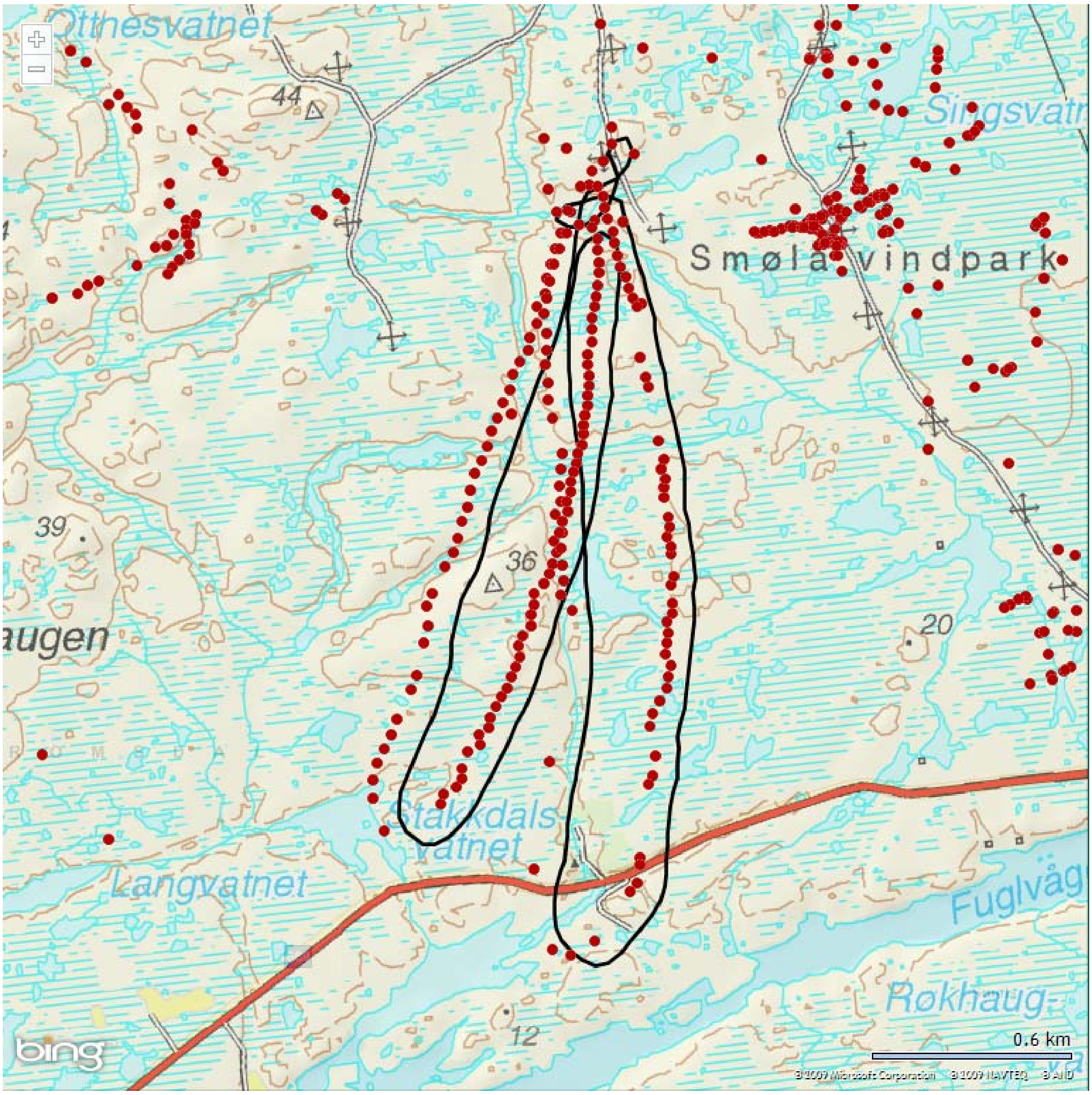


Figure 37. *Radar tracks (red dots) together with the corresponding GPS position of the aircraft (black solid line).*

In addition to low visibility in parts of the route, this example clearly indicates that there is a position offset between the radar reports and the GPS data. This information is used to perform proper alignment of the radar.

The drawback of using the model aircraft itself as the test target is that the RCS of the aircraft is much more difficult to predict than the RCS of the conducting sphere. It will vary substantially as a function of the wavelength used and the aspect angle. This is due to the irregular shape and positioning of the different scatterers on the aircraft. An important prerequisite when using the model aircraft as an test target is therefore that it's RCS is measured and verified for the relevant aspect angles and radar wavelengths. This is a separate subtask in the radar performance testing effort and is performed using an anechoic chamber in the NTNU/SINTEF laboratory for antenna measurements (Figure 38).

To calculate the detection performance for a given size bird, the aircraft RCS will have to be compared to the RCS data on the species in question, and the detection range found for the model aircraft is used to calculate the corresponding detection range for the bird RCS. Simple models for the RCS of birds can be found in the literature. Even if this extrapolation is a trivial task using the radar equation, the size of the test target should preferably be in the same order of magnitude as the RCS of the birds the radar is set to detect and record.

Figure 38. *Model aircraft used as test target mounted on the swivelling table on the measurement tower in the anechoic chamber. The radar antennas are in the window to the right in the picture*. Photo: Yngve Steinheim.

2.5.1.3 Large-scale 3D radars

NINA/SINTEF have met with representatives for the Royal Norwegian Air Force Inspectorate for Air Operations, and the Norwegian Meteorological Institute regarding use of their large-scale 3D radar systems to map and develop large-scale monitoring and possibly early-warning systems for bird migration along the Norwegian coastline. The feedback from both agencies was positive, but they pointed out that they will only by capable of supporting NINA with radar-data products and cannot provide any manpower. The military data is generally classified according to national security regulations, and the most critical issue to be resolved before access can be granted is how the data can be filtered and declassified for use by NINA. This is a formal question and the Inspectorate for Air Operations wanted to take it into a more thorough consideration. NINA has therefore made a formal written request describing the need for data and support. This request is now being processed by the Royal Norwegian Air Force.

2.6 Detector and sensor systems

Subproject responsibility: Kjetil Bevanger, Lars Johnsen

Objective: Develop equipment and technology to detect birds in the close vicinity of wind turbines and learn more about bird behaviour close to the turbines and possible effects of rotor-induced air turbulence. This may create a future basis for developing methods for reducing the risk of birds being killed by wind turbines.

2.6.1 Activities and findings

The 7-camera system developed and put in place by SINTEF during the spring 2008 have been collecting data throughout the year. For the time being several terabytes is waiting to be analysed. The reason for this is that the system has a malfunction being triggered by other movements than by birds. During the summer a person has been contracted to analyse the videos manually, however, this is an impossible task due to the data volume. How to proceed with this will be discussed on a meeting with Statkraft in January 2010.

During late autumn 2009 the camera system has been serviced. One malfunctioned external hard drive has been replaced. The protective rotating window of camera 2 has stopped. The driving DC motor needs replacement brushes. Brushes are ordered and for a period the camera works without the window rotating.

2.7 Data flow and storage systems

Subproject responsibility: Roald Vang, Stig Clausen

Objectives: Develop a comprehensive technical infrastructure for efficient data flow, storage, retrieval, management and analytical use of bird-detection data from installed camera systems and the MERLIN radar and applied satellite telemetry.

The data flow infrastructure which was established in 2008 has been working as intended. However, we have seen the need to "tune" the data flow, and also to split the data into more fragmented databases and file systems to gain better performance when querying against the most interesting parts of the data. The tracks database is growing very fast (several hundreds of millions records) and with these amounts of data, filtering and splitting of the data is essential.

As a part of the data-mining task described in 2.6.1 we have also installed Microsoft SQL Server Analysis Server 2008 so that we can utilize the powerful data-mining features inside SQL Server. We have created several data-mining models to use with the data, and are trying to correlate the different types of radar tracks (birds, ground clutter, rain clutter, etc.) with for instance the different clusters produced when using the *Microsoft Clustering Algorithm*.

We have also imported weather data from The Norwegian Meteorological Institute, which we try to attach to the data when using the mining models.

2.7.1 Visualization of radar tracks

NINA has developed a web application, "WebTracks", which allows radar tracks to be visualized together with ground-truth data, weather data and tracks from model-aircraft tests (Figure 39). At the moment it is only used as an internal web application. It gives an instant view of where the radar might have low visibility. It also visualizes where the radar loses track of the object, and splits tracks into multiple segments, where they should have been contiguous.

By selecting and displaying ground-truthed data, or model aircraft tracks, together with tracks from the radar database in the same time interval, an instantaneous overview of the radar-tracking capabilities can be obtained.

It is possible to overlay both topographical maps, and clutter maps in the map window of the application. Together with colour coding of the objects height, the clutter map indicates where the object should be visible for the radar.

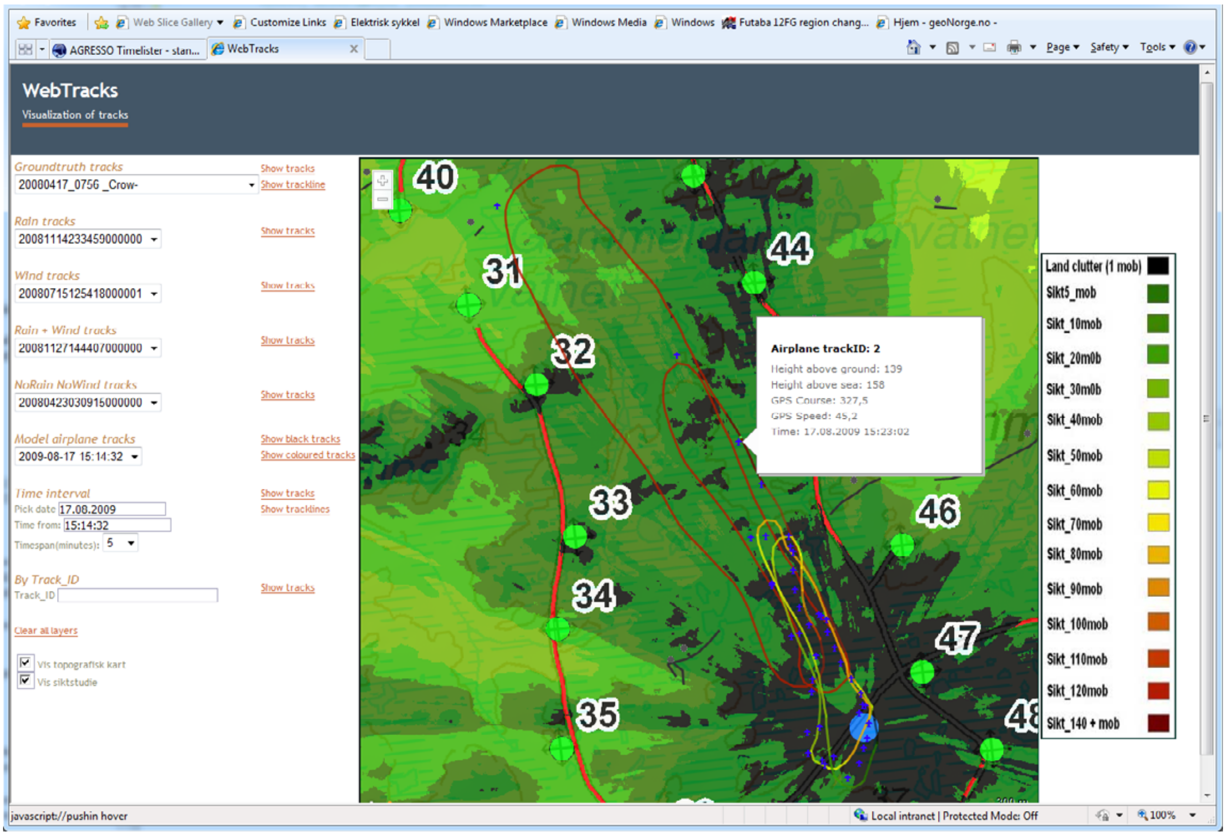


Figure 39. *Screenshot of the WebTracks web application.*

2.8 GIS, visualization and terrain modelling

Subproject responsibility: Frank Hanssen

Objektives: Visualize the bird real activity patterns in 3D, establish a methodology and model possible conflict areas between birds and wind-power plants.

2.8.1 Activities and findings

The activities in 2009 have mainly focused on terrain modelling and GIS-based methods to calibrate radar data (clutter-modelling).

Based on laser elevation data from the laser scanning of Smøla in 2008 a high resolution terrain model (1x1 meter) was established in March 2009. The LIDAR data was delivered in LAS- format and the category 2 (ground points) were imported into a geodatabase as multipoint geometry (XYZ). The average point spacing in the dataset is 2 ground points per m^2. The multipoint data was then imported into a terrain model and finally converted to a GRID with floating point values (decimal elevation). All sea and lake pixels in the GRID were then masked by water polygons from FKB (1:5000) to get rid of disturbing water surface textures measured in the laser scanning.

Photo 11. *Frank Hanssen elaborating on the GIS work performed at the 2009 Annual Meeting.* Photo: Kjetil Bevanger.

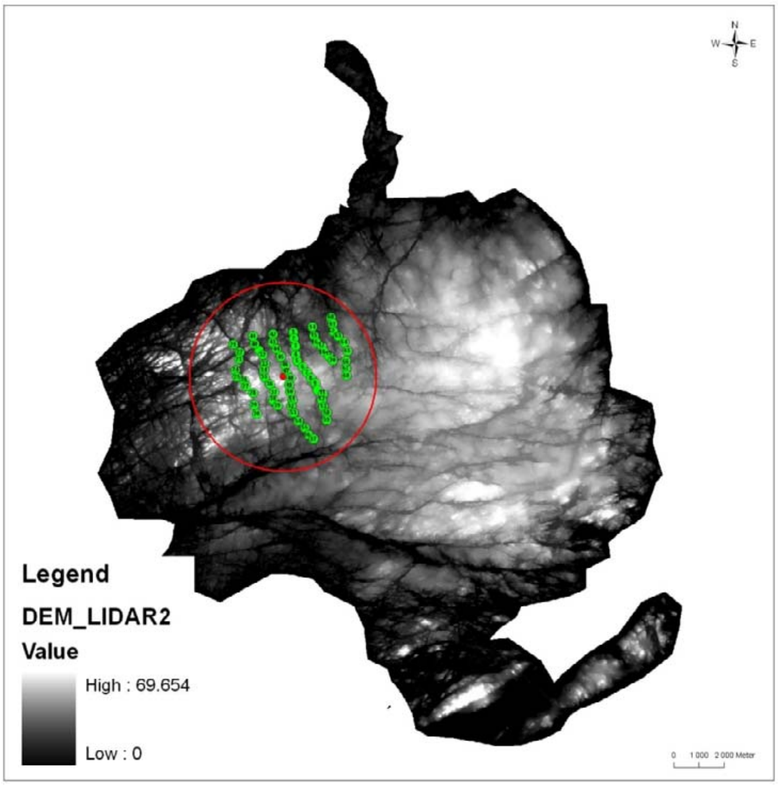


Figure 40. *LIDAR DEM of Smøla. Red circle indicates the instrumented radar coverage from the current radar location.*

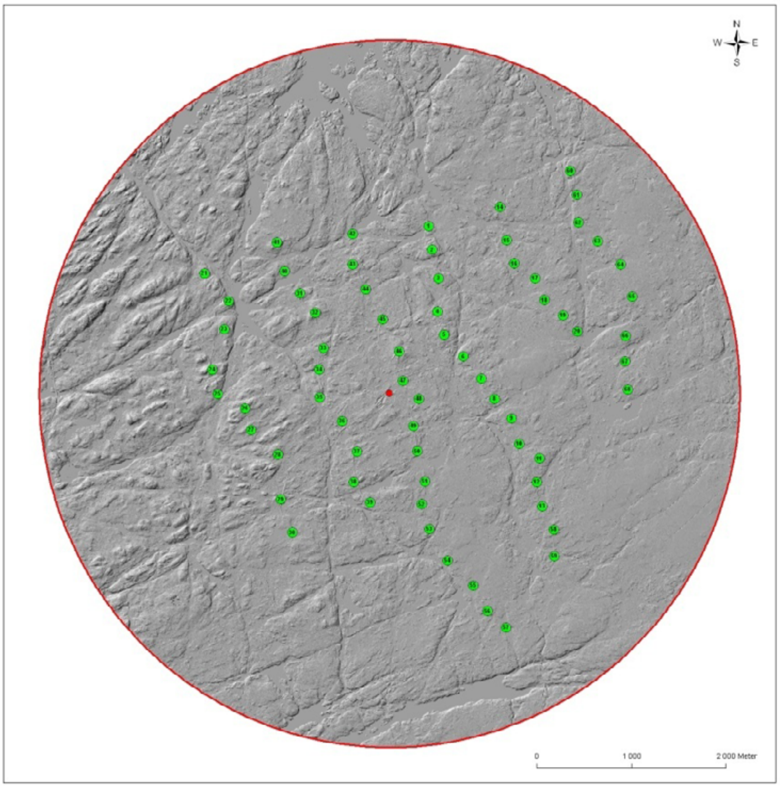


Figure 41. *Calculated hillshade of the LIDAR DEM in the instrumented radar coverage from the current radar location (red dot)*.

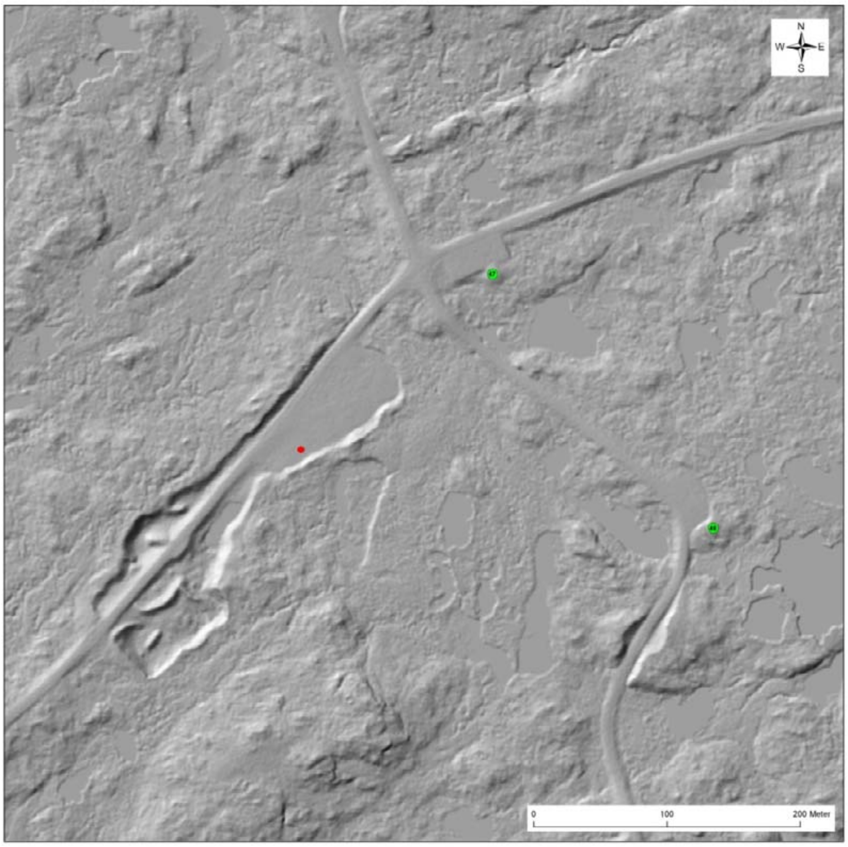


Figure 42. *Calculated hillshade around the current radar location (red dot).*

The LIDAR-DEM model is an important input in the modelling of theoretical land-clutter areas and areas with wind-turbine interference (Figure 40, 41 and 42). These clutter and interference areas reduce the radar-detection performance and have to be flagged as clutter in the database. So far has the clutter modelling has only considered the horizontal S-band radar.

The land clutter has been modelled in which the surface reflectivity is given by:

$$\sigma^0 = \gamma \sin\psi$$

with γ as a parameter describing the scattering effectiveness of the surface, and $\sin\Psi$ as the sine-transformed grazing angle at the surface in each radar resolution cell.

The relationship between land-clutter reflectivity versus grazing angle for various types of terrain is described in Figure 43.

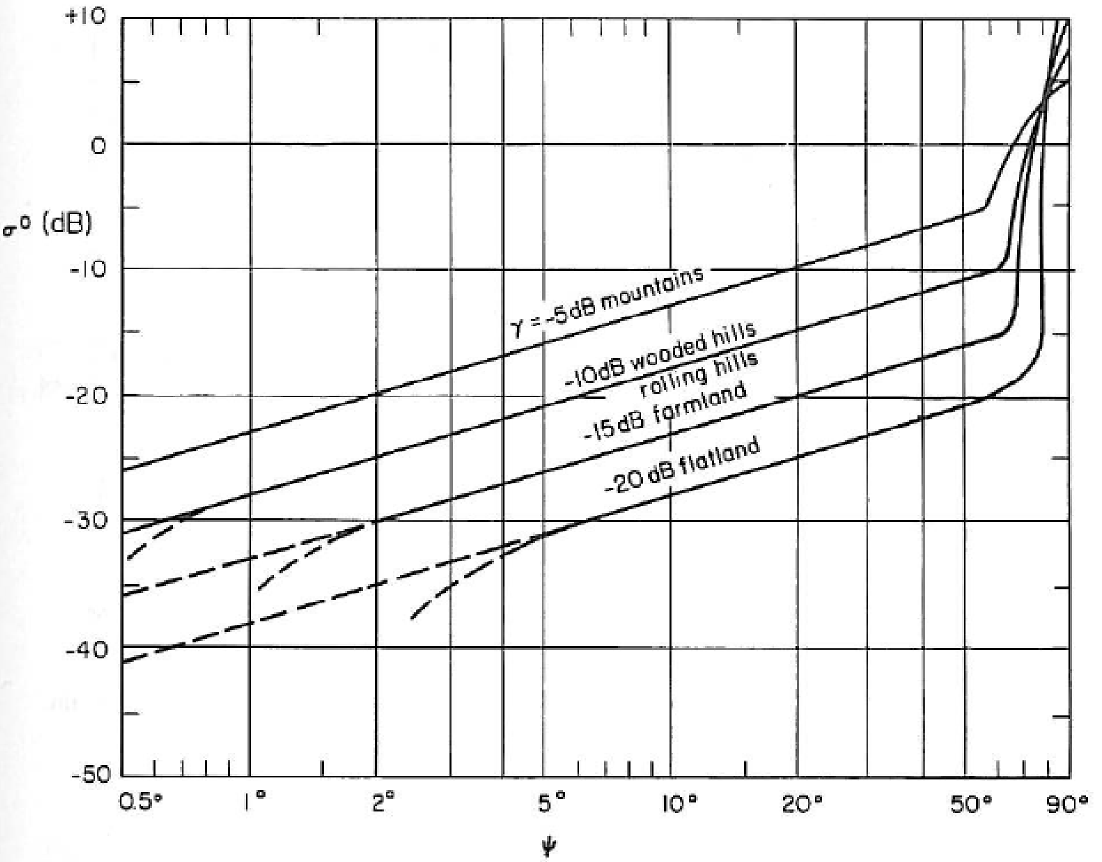
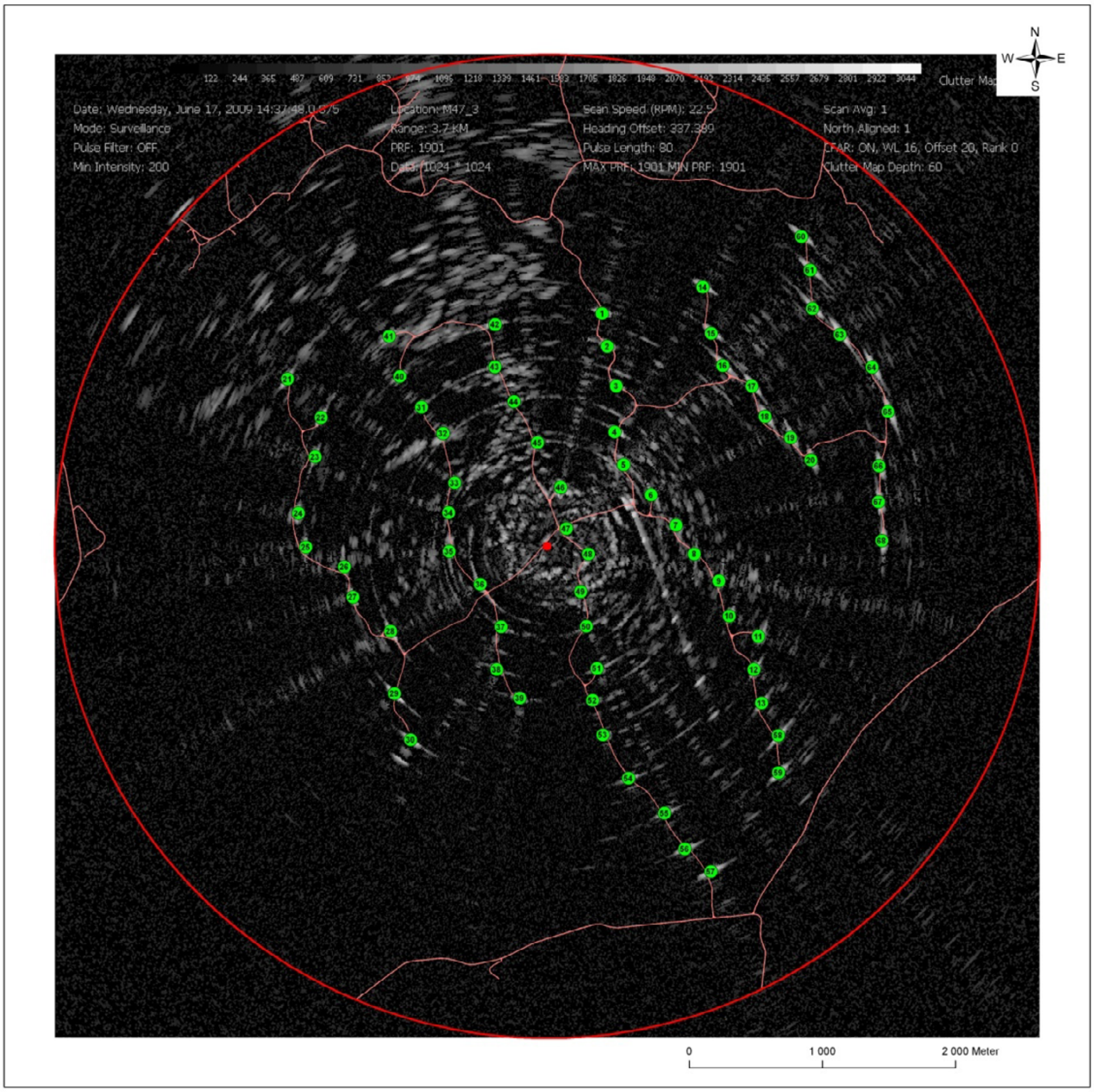


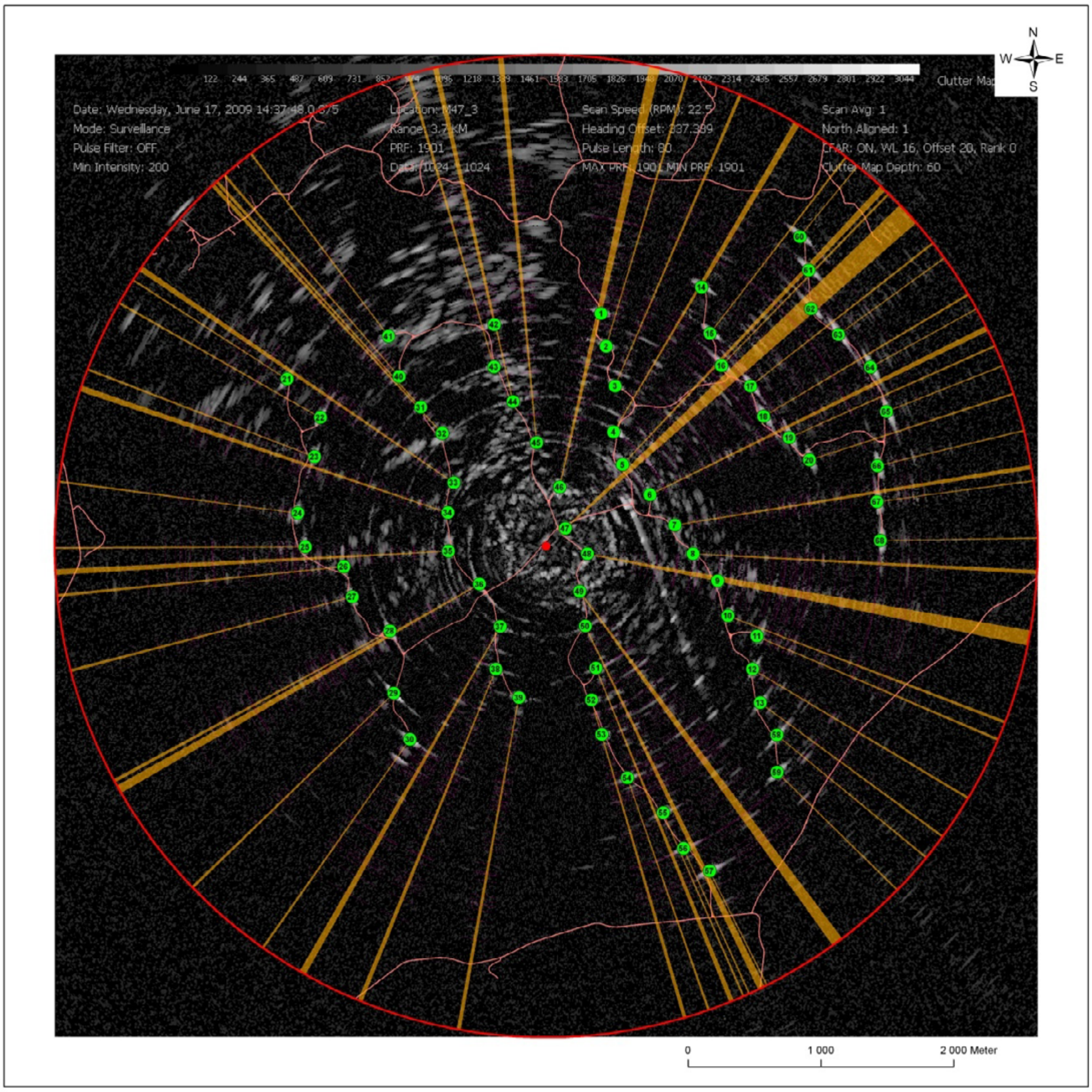
Figure 3.6.2 Land clutter reflectivity *versus* grazing angle.

Figure 43. *The relationship between land-clutter reflectivity versus grazing angle for various types of terrain* (after Barton 1988).

Based on this (cf. Figure 43) reflectivity values for all land-cover types (vegetation map AR5 1:5000) in the wind-power plant are estimated. The grazing angles of the terrain are calculated from the terrain model, derived slope and aspect using vector calculus. The grazing angles in visible areas from the radar (based on view-sheds) will be averaged for each radar resolution cell. Areas representing turbine interference are modelled using ordinary view-sheds from the radar location to all wind turbines (Figure 44 and 45).



Figur 44. *MERLIN Clutter map. White areas are representing land surface clutter and turbine interference detected by the MERLIN processor.*



Figur 45. *MERLIN Clutter map compared to modelled turbine interference.*

The land surface clutter model is nearly completed, but has to be further improved and tested before it is applied into the database as a mask to flag clutter pixels. This is an important step in order to interpret the database.

In 2009 there has been no activity on 3D-visualization. For the rest of 2009 and 2010 the focus will be to consolidate the land surface clutter model and to start the analysis on bird activity and bird collisions. The results from these analyses will be visualized in 3D.

3 Publications, lectures, coverage in public media and conference participation

3.1 Publications

Bevanger, K., Clausen, S., Flagstad, Ø. Follestad, A., Gjershaug, J.O., Halley, D., Hanssen, F., Lund Hoel, P., Jacobsen, K.-O., Johnsen, L., May, R., Nygård, T., Pedersen, H.C., Reitan, O., Steinheim, Y. & Vang, R. 2008. "Pre- and post-construction studies of conflicts between birds and wind turbines in coastal Norway". Progress Report 2008. NINA Report 409. 55 pp.

Bevanger, K., Berntsen, F., Clausen, S., Dahl, E.L., Flagstad, Ø., Follestad, A., Halley, D., Hanssen, F., E., Hoel, P.L., Johnsen, L., Kvaløy, P., May, R., Nygård, T., Pedersen, H.C., Reitan, O., Steinheim, Y. & Vang, R. 2009. "Pre- and post-construction studies of conflicts between birds and wind turbines in coastal Norway" (BirdWind). Progress Report 2009. - NINA Report 505. 70 pp.

May, R. & Nygård, T. 2009. Spatial assessment of white-tailed sea eagle collision risk at the onshore wind-power plant on the island of Smøla. 2nd European Congress of Conservation Biology. Conservation biology and beyond: from science to practice. Czech University of Life Sciences, Prague. September 1-5, 2009.

Nygård, T., Bevanger, K., Dahl, E. L., Flagstad, Ø., Follestad, A., May, R., Reitan, O. & Schulze, J. 2009a. Juvenile White-tailed Sea Eagles' (*Haliaeetus albicilla*). Movement Patterns at Smøla Wind-farm in Norway Determined by Satellite Telemetry. Raptor Research Foundation annual meeting. Pitlochry, Scotland. 30. Sept. - 3. Oct. 2009.

Nygård, T., Jacobsen, K.-O. & Dahl, E. L. 2009b. The use of satellite transmitters in eagle research in Norway. Microwave Telemetry, Inc. 2009 bird and fish tracking conference. Elliot City, Maryland, USA. 24-26 March 2009.

3.2 Lectures and conference participation

Bevanger, K. 2008. "Pre- and post-construction studies of conflicts between birds and wind turbines in coastal Norway" og "Optimal design and routing of power lines; ecological, technical and economic perspectives". Foredrag på intern FoU-dag i NVE (KTE/KTN) 9. desember, Oslo.

Bevanger, K. 2009. Vindkraft, kraftledninger og fugl – en kunnskapsstatus. – Foredrag på workshop om vindkraft, kraftledninger og hubro, 24. februar 2009, Trondheim. Arrangør NVE og DN.

Bevanger, K. 2009. Research activities on Smøla focusing bird responses to the wind-power plant. Foredrag i tilknytning til Bernkonvensjonens "On the spot apprisal", Smøla 16 June 2009.

Bevanger, K. 2009. Introduction and a brief summary of the Smøla wind-power project. Annual Meeting, 23-24 March. - Havfiskesenteret, Smøla.

Bevanger, K. 2009. BirdWind and OPTIPOL. Kick-off seminar CEDREN 29.09., Trondheim.

Bevanger, K. BirdWind. TrønderEnergi, Trondheim. 20.11.2009.

Dahl, E.L. & Nygård, T. 2009. Havørn og vindkraft på Smøla. Presentasjon for TrønderEnergi 20.11.2009. Trondheim.

Dahl, E.L. 2009. Pre- and post-construction studies of conflicts between birds and wind turbines in coastal Norway. Foredrag på Energiregion Møre sin energileir for lærere. 22.09.2009, Smøla

Dahl, E.L. 2009. White-tailed eagle in Smøla Windfarm. Monitoring and population modeling. Foredrag under høringsmøte Bernkonvensjonen. 16.06.2009, Smøla

Dahl, E.L. 2009. White-tailed eagle in Norway. Monitoring and population modeling. Annual Meeting, 23-24 March. - Havfiskesenteret, Smøla.

Follestad, A. 2009. Sum-effects of wind power development and environmental aspects connected to offshore wind turbines. Annual Meeting, 23-24 March. - Havfiskesenteret, Smøla..

Hanssen, F. 2009. Terrain and clutter modeling – the road ahead. Annual Meeting, 23-24 March. - Havfiskesenteret, Smøla.

Hoel, P.L. 2009. Do the wind-power plant on Smøla affect the WTSE behaviour? Annual Meeting, 23-24 March. - Havfiskesenteret, Smøla.

Johnsen, L. 2009. Camera monitoring – further development of the project and views on lights to make the wind turbines more visible (in situ or an experimental design to test UV-light, flashing frequencies etc. Annual Meeting, 23-24 March. - Havfiskesenteret, Smøla.

May, R. 2009. 1 year's worth of Bird Radar: what have we learned? Annual Meeting, 23-24 March. - Havfiskesenteret, Smøla.

May, R. 2009. Radar studies on white-tailed sea eagle at the onshore wind park on the island of Smøla. Presentasjon for Vitenskapsmuseet 12.05.2009 Smøla.

May, R. 2009. Spatial assessment of collision risk in white-tailed sea eagle at the onshore wind power plant on the island of Smøla. Foredrag i tilknytning til Bernkonvensjonens “On the spot appraisal” 16.06.2009 Smøla.

May, R. 2009. Pre- and post-construction studies of conflicts between birds and wind turbines in coastal Norway. Presentasjon for NTNU Summer school 15.07.2009 Smøla.

May, R. 2009. *Pre- and post-construction studies of conflicts between birds and wind turbines in coastal Norway*. Foredrag på Miniseminar MSc-programmet i Natural Resources Management (NTNU/NINA/DN) 11.11.2009, Trondheim.

May, R. & Nygård, T. 2009. Spatial assessment of white-tailed sea eagle collision risk at the onshore wind-power plant on the island of Smøla. Foredrag på European Conference for Conservation Biology (Society for Conservation Biology) 03.09.2009, Prag, Tsjekkia.

May, R. 2009. Pre- and post-construction studies of conflicts between birds and wind turbines in coastal Norway. Tools and Techniques. Presentasjon for TrønderEnergi 20.11.2009. Trondheim.

Nygård, T., Bevanger, K., Dahl, E.L., Flagstad, Ø., Follestad, A., Halley, D., May, R., Pedersen, H.C., Reitan, O. & Schultze, J. 2009. Juvenile White-tailed Eagles’ Movement Patterns at Smøla Wind-farm in Norway Determined by Satellite Telemetry. Foredrag på Raptor Research Foundation Annual Meeting (Raptor Research Foundation) 02.10.2009, Pitlochry, Skottland.

Nygård, T., Jacobsen, K.-O. & Dahl, E.L. 2009. The use of satellite transmitters in eagle research in Norway. Microwave Telemetry, Inc. 2009 bird and fish tracking conference. Elliot City, Maryland, USA. 24-26 March 2009.

Pedersen, H.C. 2009. Why are the ptarmigans killed within the Smøla wind-power plant – and what are the consequences for the ptarmigan population? Annual Meeting, 23-24 March. - Havfiskesenteret, Smøla.

3.3 Coverage in public media

Adresseavisen - 10.12.2008. Vindmøllene dreper mer ørn. Kjetil Bevanger.

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TV2 – 13.12.2008. Vindmøller skaper fugledød. Kjetil Bevanger.

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5 Appendices

Appendix 1. *Program for the Anual Meeting on Smøla 2009*.

MEETING ON WIND POWER AND BIRDS ON SMØLA MARCH 23-24 2009

The yearly scientific meeting on wind power and birds connected to the research project "*Pre- and post-construction studies of conflicts between birds and wind turbines in coastal Norway*" will take place at Havfiskesenteret on Smøla Monday 23-Tuesday 24, March 2009. The meeting is meant to be an arena where the involved scientists can meet representatives from the institutions, which, together with the Norwegian Research Council, are funding the project (Statkraft, EBL, NVE, DN). Due to limited capacity with respect to accommodation facilities we normally have a 3 person limit for each institution; however, we are flexible regarding this.

Monday 23 March

1145-1230	Lunch at Havfiskesenteret
1230-1255	.Welcome, status, relations to CEDREN etc. (Kjetil Bevanger)
1300-1325	Why are the ptarmigans killed within the Smøla wind-power plant – and what are the consequences for the ptarmigan population? (Hans Chr. Pedersen)
1330-1355	Status for the WTSE in Norway. What data do we need to make a prediction model for what a WTSE population can take of human-induced mortality? (Espen Lie Dahl
1400-1425	Do the wind-power plant on Smøla affect the WTSE behaviour? (Pernille Lund Hoel)
1430-1450	Coffee
1450-1515	One year with a bird radar – what have we learnt? (Roel May)
1520-1545	Use of weather radar as a tool for monitoring bird migration. (Mark Desholm)
1550-1610	Terrain and clutter modeling – the road ahead. (Frank Hanssen)
1600-1800	Sum-effects of wind power development and environmental aspects connected to offshore wind turbines. Views from NVE, DN, EBL and Statkraft (Arne Follestad initiate the discussion).
1900	Dinner and social gathering

Tuesday 24 March

0800-0900	Breakfast
0900-0925	Olle Håstad presents his project proposal
0930-1000	Camera monitoring – further development of the project and views on lights to make the wind turbines more visible (in situ or an experimental design to test UV-light, flashing frequencies etc.) (Lars Johnsen)
1000-1100	Discussion – views from NVE, DN, EBL and Statkraft on the road ahead
1100-1145	Lunch
1145	Departure

Some minor changes to the program may take place. Please report back as soon as possible (at the latest on March 5) due to confirmation needs for accommodation facilities.

Practical instructions:
Accommodation at Havfiskesenterert. Those arriving from Trondheim will take the speedboat at 0800 in the morning, We arrive on Smøla (Edøy) at 1040 and will be transported by bus to Havfiskesenteret. It is also possible to take an aircraft to Kristiansund and car/speedboat from there.

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